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TACTICS DIVISION
TACSPIEL GROUP

CARMONETTE

A Concept of Tactical War Games

by

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FOREWORD

This Staff Paper presents a concept of war gaming which is under active consideration by ORO Study 15.1. It is expected to yield quantitative results in the near future. However, war gaming and its application is now receiving such widespread consideration by Army Schools, Commands and other agencies that a wide distribution of the concepts presented in this paper seems desirable.

While this paper does not put forth specific conclusions and recommendations which require Army action, it is hoped that the discussion herein will make a positive contribution to the continuing evaluation of war gaming by Army agencies.

CARMONETTE

A Concept of Tactical War Games

INTRODUCTION

War Games

The mission of the TACSPIEL Study group* at ORO is to develop war gaming techniques for research purposes at all tactical levels. It is instructive to discuss briefly the connection between the TACSPIEL tactical war games being developed at ORO and previous efforts to use war gaming techniques for research purposes. The war game or map exercise has been used for many hundreds of years in an attempt to simulate military operations. Success in such simulation would have the obvious and considerable benefit of testing the value or effectiveness of new weapons, fighting techniques, or war plans. However, all efforts to use the war game for such purposes in the past have been severely hampered by a critical limitation of the means available to conduct such war games, associated with the uncertainty or play of chance which is so prominent a feature of warfare. Thus, since even in principle we may not assume the outcome of any given battle as a certainty, the outcome of battle must be measured by the probability with which various alternative results may be expected. Therefore the results of a single war game will indicate at most but one of the possible outcomes. It will be necessary to repeat the battle calculations allowing nothing but the play of chance to vary and so identify the spectrum of the possible outcomes and the associated frequency distribution.

A second requirement of the war gaming process is that a comparison be possible between the outcome of the battles using one weapon system and the outcome of similar battles using another weapon system, <u>all other things being held fixed</u>.

In other words, we must be able to repeat the battle simulation many times while holding fixed all parameters except that one under investigation.

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*ORO Study 15.1; CDOG para 120 h.

Attempts to repeat map exercises "played by hand" wherein numerous decisions are made throughout the battle by the human player have floundered on two points: (1) the intrinsic complexity of battles results in each game involving sometimes dozens of players and days, weeks, or even months of their time to complete a single game.1/ Repetition of such games a hundred times or more, even if possible, would be prohibitively expensive. (2) The requirement that all parameters be held fixed except that one under investigation during these numerous games is frustrated by the dependence on the intuitive judgment of the human participants during the play of the game. For example, the players must resist the temptation to use in later games lessons learned in previous games, so long as such learned tactics themselves are not the variable being investigated.

Any serious attempt to use operational simulation for war games as a research tool must therefore cope with these two problems. A most essential feature of CARMONETTE is that it provides for the codification of all the decision processes occurring in the battle so that once stated, those decisions may be accurately repeated as many times as is required.* Once this has been done, not only is it possible to repeat battles with all factors truly constant except the one under investigation, but also mechanical computing aids may be used to interpret the codified decision processes and speed up the overall operation by factors of perhaps a thousand. In this way we hope to apply the war game CARMONETTE to problems of military interest identical to those posed by professional military men for hundreds of years, but on a vastly larger scale.

Conversely, we must anticipate the same fundamental limitations on theoretical analysis using CARMONETTE as has always restricted the use of theoretical calculations to predict the future. Theoretical analysis not associated with a substantial experimental program is of very little value.

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* This does not eliminate judgment from the game, for that is impossible. Command decision—human decision—is the essential component of the operation of any organization. The effect is to require that judgment enter the play of the game in the form of rules formulated by experienced and responsible authority. When a war game is applied for training purposes, carefully controlled exceptions must be made to this requirement. This is discussed briefly in the last section of this paper.

NEW TACTICAL CONCEPTS

Feasibility depends on:

Strategic Objectives

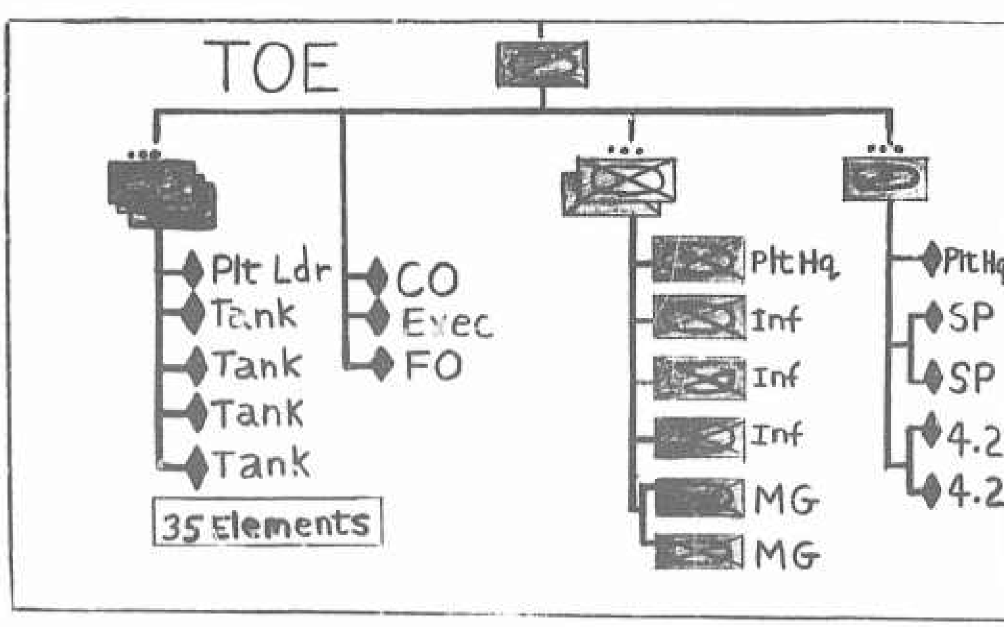
Logistics

Production

Research and Development

Small Unit Combat Effectiveness

Figure 1



A representative TOE for combined arms teams

Figure 2

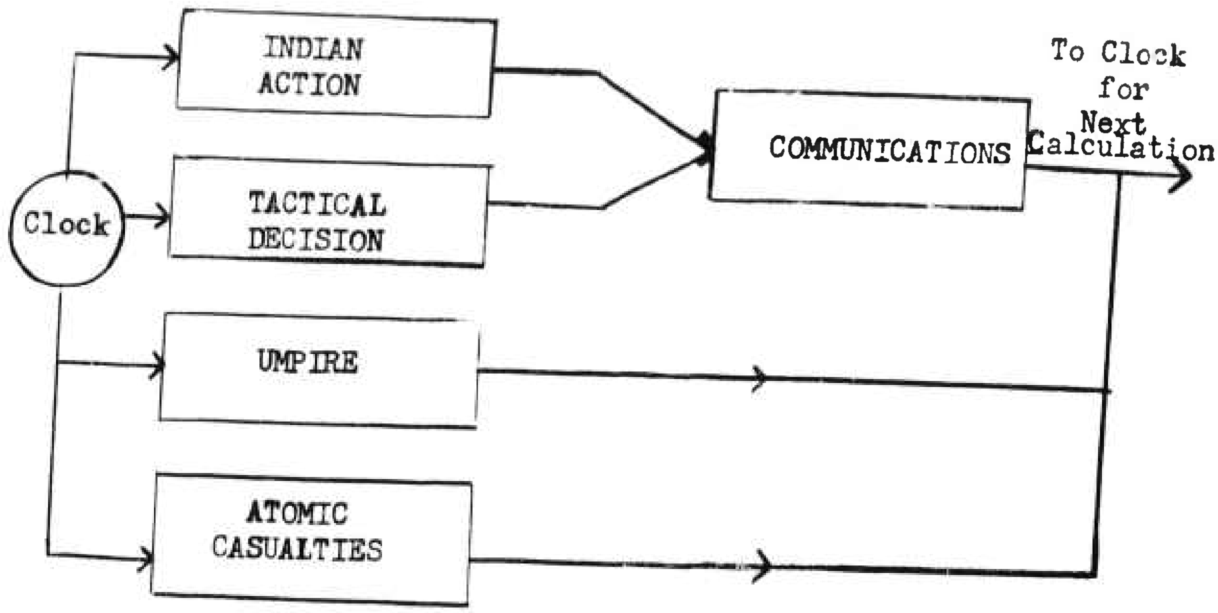


Figure 3

The computer must perform these various functions in a realistic time sequence determined by "clock".

CARMONETTE

CARMONETTE is a mathematical model of battle, of Monte Carlo type, which simulates in a simple straightforward manner, the step by step progress of an isolated battle. It is designed so that all the calculations may be carried out on standard general purpose digital computers, except that a limited number of high level decisions may be injected into the battle during the calculations. ~~Two Technical Memoranda have been~~ published describing the preliminary work.[2,3]

CARMONETTE consists of two parts. The first, which details the manner of simulation of the combat activities of the individual participants in each battle, is in a high state of development. The second part, which deals with the integration of these separate combat elements into sensible and meaningful battles, is less well established.

There are numerous new concepts of warfare requiring investigation. Figure 1 (V3182) lists important factors which must be considered in determining the feasibility of such concepts. Ultimately all these factors must be investigated. For the moment let us consider CARMONETTE as a war gaming scheme to determine only the combat effectiveness of small units employing the new concept. In the present instance, the small units of interest are of around company size -- some hundreds of men and some dozens of heavy weapons like tanks. For example, the concept may involve a radically new tank design. Figure 2 (V2705) lists the organization that might be associated with an armored unit using new tanks. It might include 18 tanks, 2 platoons of infantry, some mortars, and perhaps some special weapons such as surface-to-surface guided missiles. (CARMONETTE has the capability of including up to 36 independent combat elements on each side.)

Structure of Battle

Our problem is to design a model of battle which can simulate typical or critical combat actions to test the effectiveness of the proposed tank company. Figure 3 (V2891) indicates the distinct components of such battles which must be provided by the model. First there are the ACTIONS of the distinct combat elements -- separate tanks and small groups of men like the squad or a gun crew. Secondly there is the UMPIRE function designed to monitor the exchange of information and the information gathering procedures of the distinct combat elements so as to limit these processes according to the restrictions imposed by the performance characteristics of the hardware and the cover and concealment associated with the terrain. The calculations of ATOMIC CASUALTIES resulting from the use of atomic weapons is not a distinct component of battle but involves such special problems and massive calculations that it is here listed separately. The TACTICS routine is responsible for integrating the separate combat actions of the individual combat elements into a sensible battle. Finally, the interactions between one combat element and another, especially the commanders of the various tactical units, make use of the company communication system which is therefore an important component of the battle to be simulated. These routines are assembled into a battle by the CLOCKS routine which orders the different events in time.

I will first describe the manner in which the separate ACTIONS of the combat elements are simulated and mention the nature of the COMMUNICATIONS and UMPIRE routines. Next I will discuss our proposal for simulating the major tactical decisions of the unit commanders who must integrate the individual actions into a sensible battle plan. Finally I will note briefly some points bearing on the application of the model.

SIMULATION OF SEPARATE COMBAT ELEMENTS

1101 Computer Battle Film

To get across the idea of these combat actions I have included stills from a cartoon using trial results of some early test battles[2/] programmed for the ERA 1101 computer to investigate the technical feasibility of CARMONETTE. The battle depicted for this cartoon is not presumed to have any particular military significance although it has been put in a setting in Western Europe of some intrinsic interest. The battle takes place on a piece of ground a little over a mile square, about 50 miles south of the zonal boundary in Bavaria. Blue is deployed as shown on the west (Figure 4) and is ordered to attack Red on the northeast. Blue consists of a reinforced tank company of 3 tank platoons, a platoon of armored infantry, and a battery of 4.2" mortars (not shown on the map). This is a total of 17 tanks, 3 squads of infantry, and 12 mortars. Red consists of a company of ten T34 tanks, a company of five SU 100 self-propelled guns, and a company of nine squads of infantry. Figure 5 shows the initial position of the separate combat elements with reference to the 100 meter grid square system superimposed on the map. All the maneuver of the combat elements is related to these 100 meter grid squares. The Blue tank platoon to the northwest is to remain in

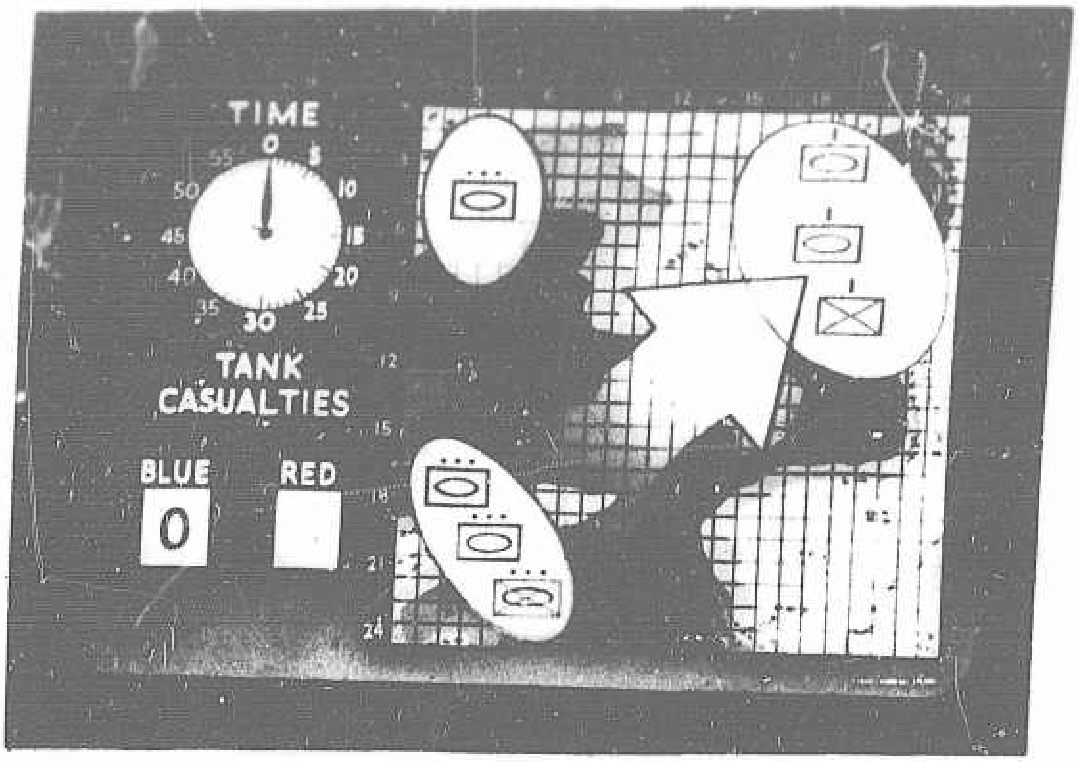


Figure 4

Blue forces deployed along west are to attack Red forces on northeast.

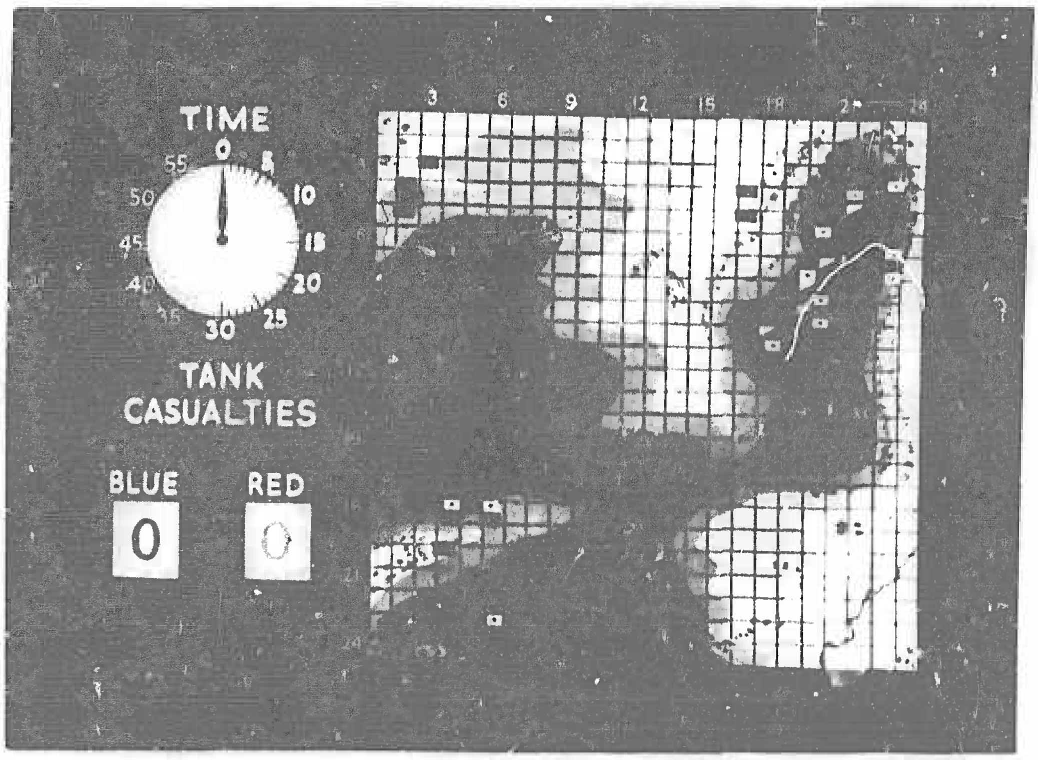


Figure 5

There are 17 Blue tanks and 3 infantry squads deployed along west. Red forces on the northeast include ten T34 tanks (solid rectangles), five SU 100 guns (diagonally slashed rectangles) and 9 squads of dismounted infantry.

position firing on the Red forces while the remaining Blue units in the southwest make a frontal attack up the hill into the Red position. As the attack starts (Figure 6) the assaulting Blue units start to move towards their terrain objective. Figures 7 thru 12 depict the movement of the assaulting Blue forces during the first 15 minutes of the battle simulation during which time (for these trial calculations) there was assumed to be no firing. Firing started at 15 minutes of battlefield time and Figure 13 shows the state of the battle at 16 minutes battlefield time, one minute after firing started. Notice the casualties are already very heavy — Blue has lost 6 tanks and Red has lost three. Figures 14 thru 20 give the further progress of the battle at 2 minute intervals until at 30 minutes battlefield time the calculations were halted. While it is not appropriate to say the battle ended at this time, the casualties were so heavy, 11 Blue vs 8 Red tank casualties, that the battle may for all practical purposes be considered over. The basic combat actions of the combat elements in CARMONETTE are those demonstrated by the cartoon — actions of fire and maneuver and the associated decision processes. However, the detailed calculations in CARMONETTE are a great deal more extensive than those used for the cartoon battle.

Battlefield Time

Before describing the simulation of individual events or actions it is appropriate to mention the way in which these are sequenced in time. Each unit has associated with it "alarm clocks" or numbers giving the time at which it will next be able to act. At the beginning of the battle (time zero) these clocks will all be set at a few seconds unless some units have been prohibited from moving or firing. The CLOCKS routine examines the clocks and finds the one with the smallest time. This corresponds to the first event that is scheduled to happen. This becomes the new battlefield time and the machine performs the calculations required to simulate the event. Suppose it was the firing of a tank. That tank's clock will be reset for the time at which it will be ready to fire again. Other clocks may be reset (for example the clock of the enemy fired upon might be reset to allow it to return fire immediately). The clocks routine then determines the next event, the battlefield time is adjusted, and calculations continue.

Firing Actions

As was indicated by the cartoon, the units in CARMONETTE from

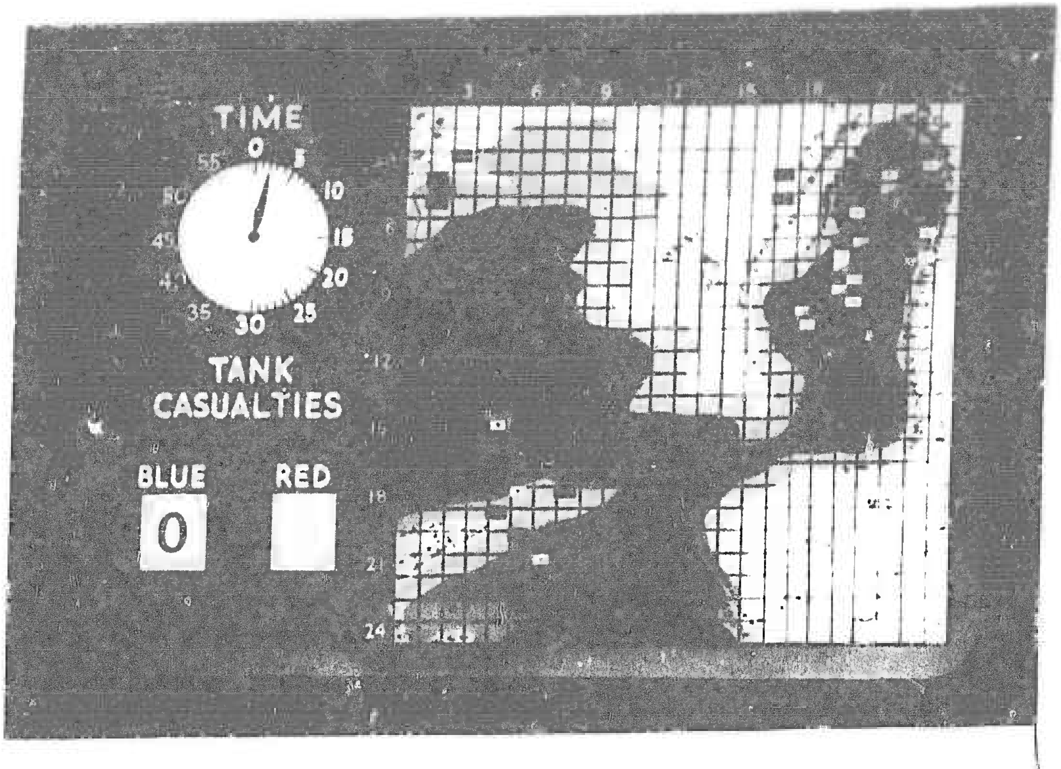


Figure 6

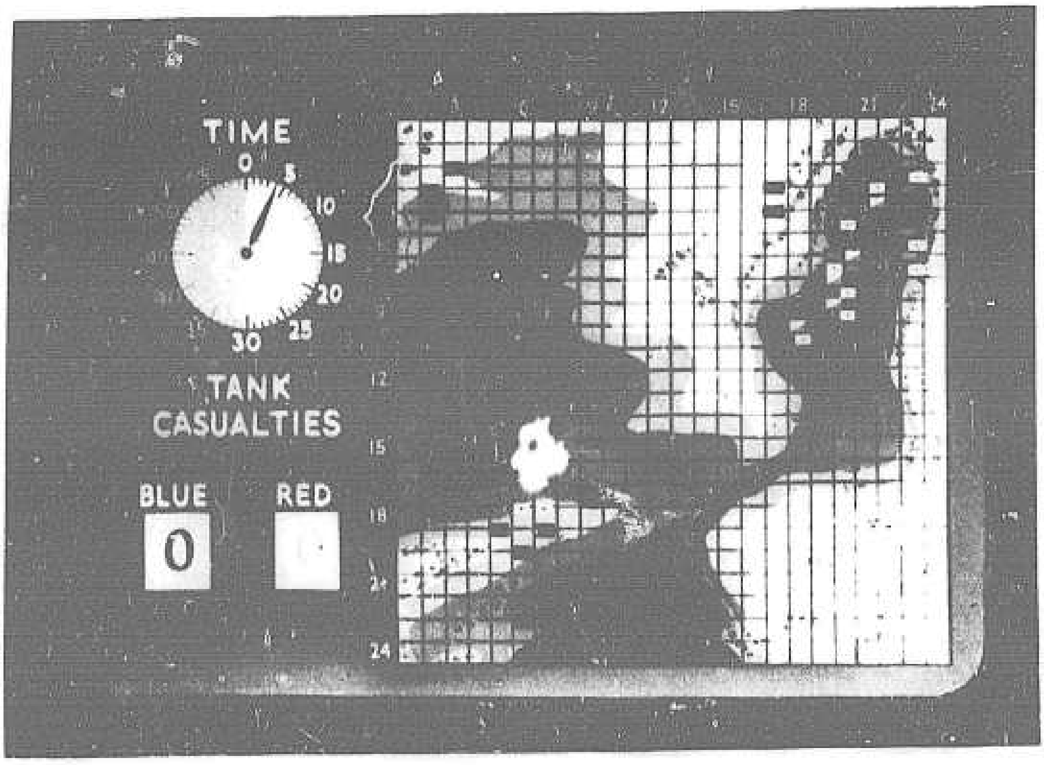


Figure 7

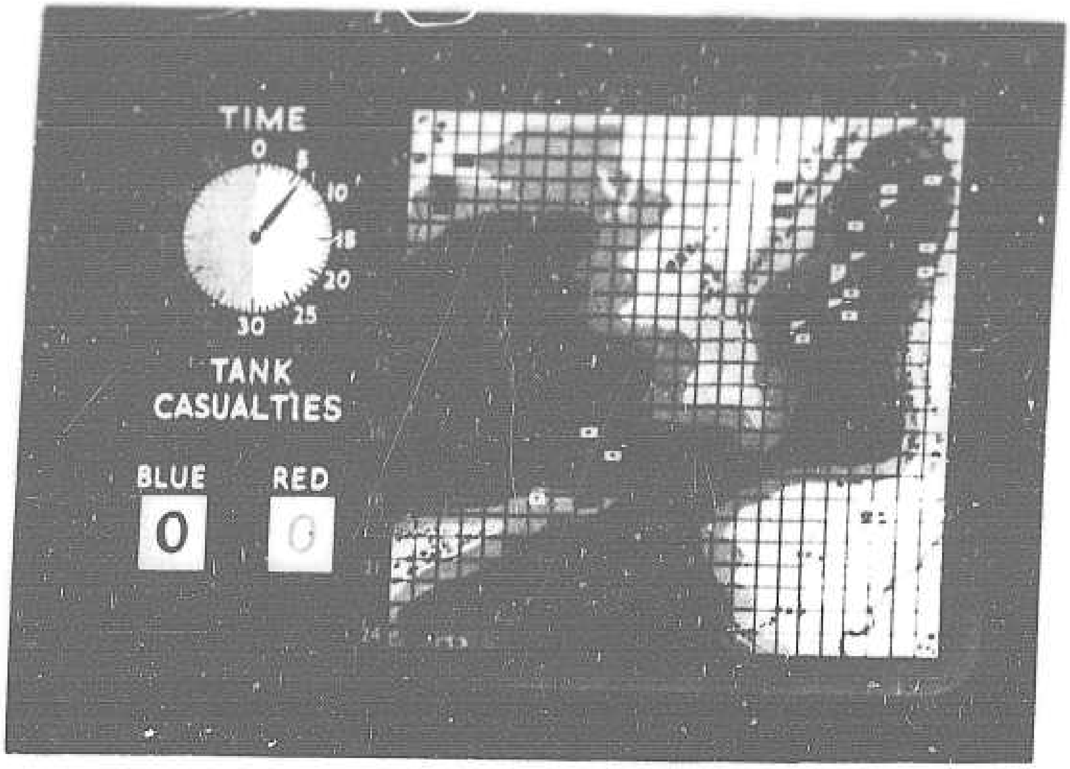


Figure 8

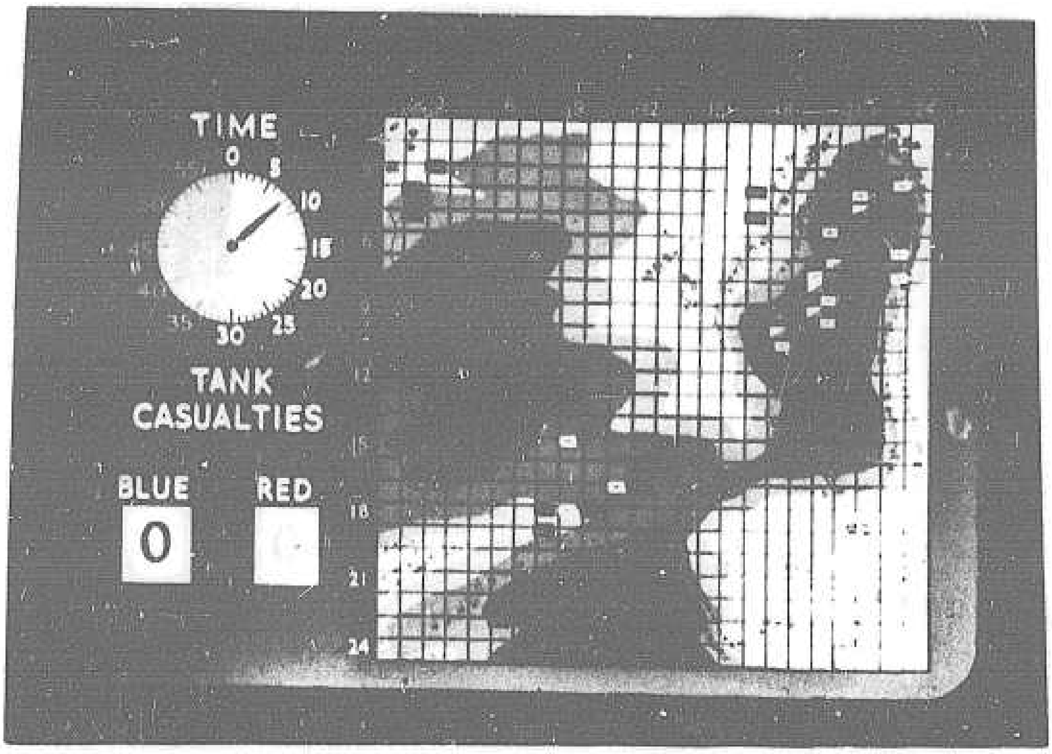


Figure 9

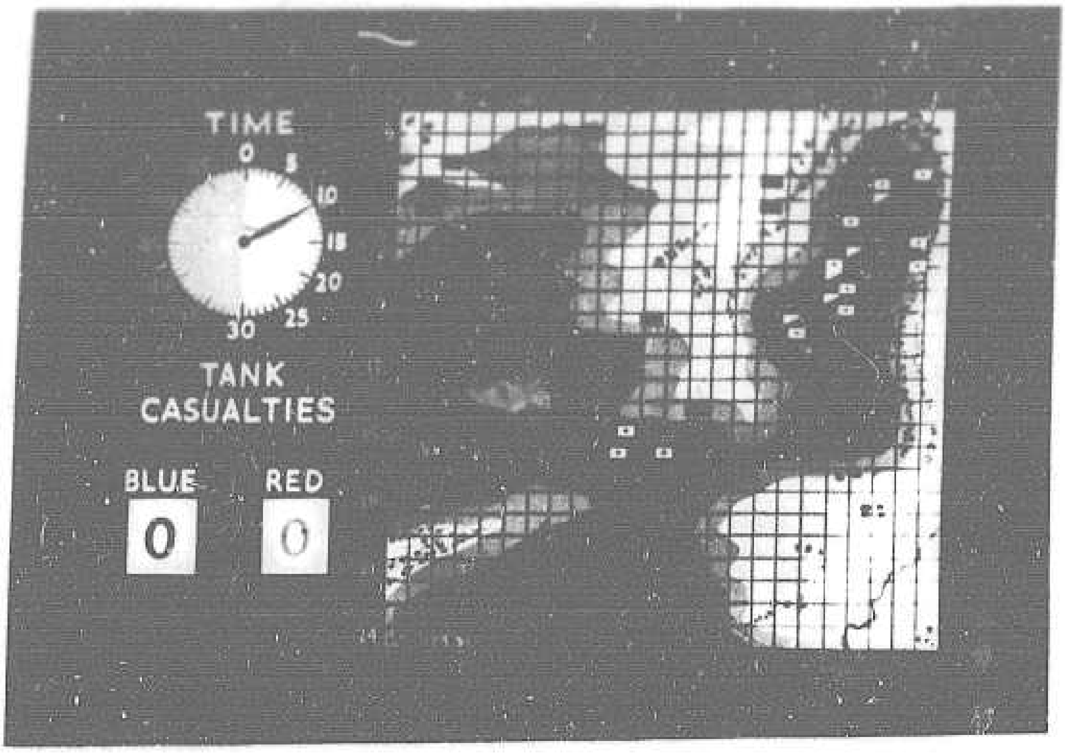


Figure 10

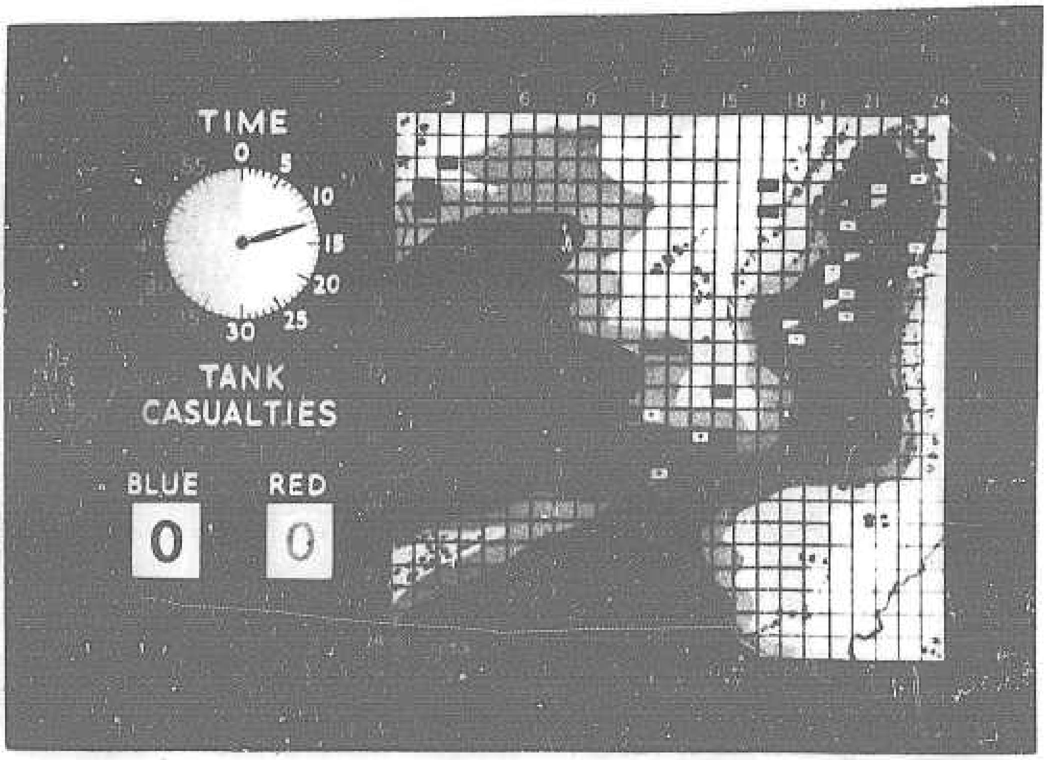


Figure 11

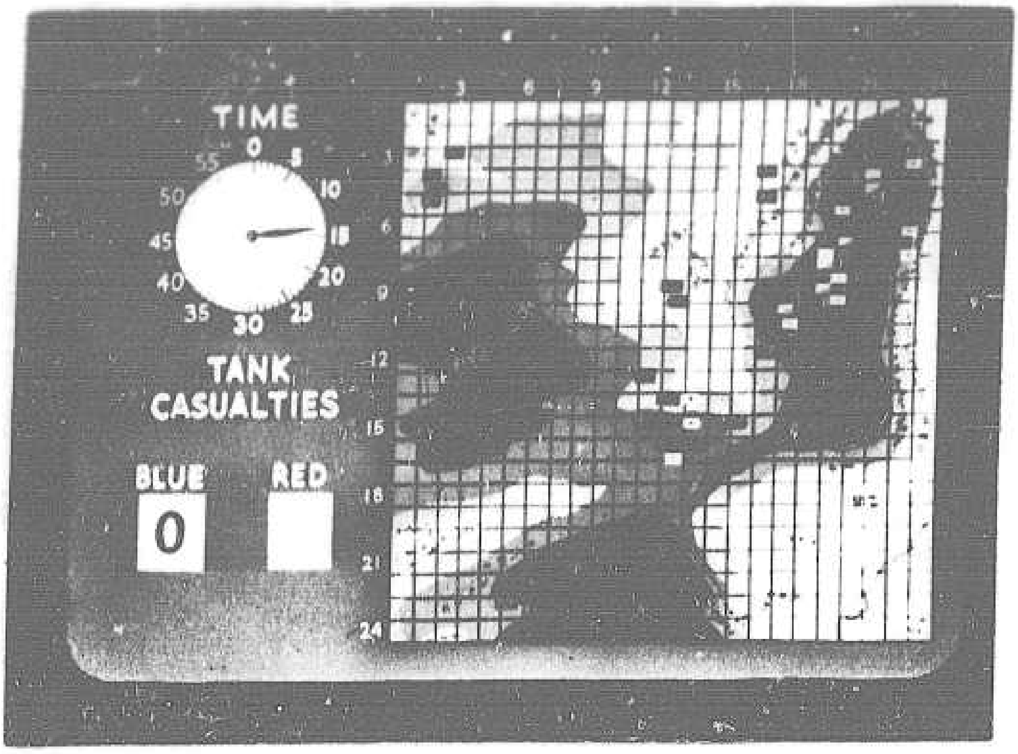


Figure 12

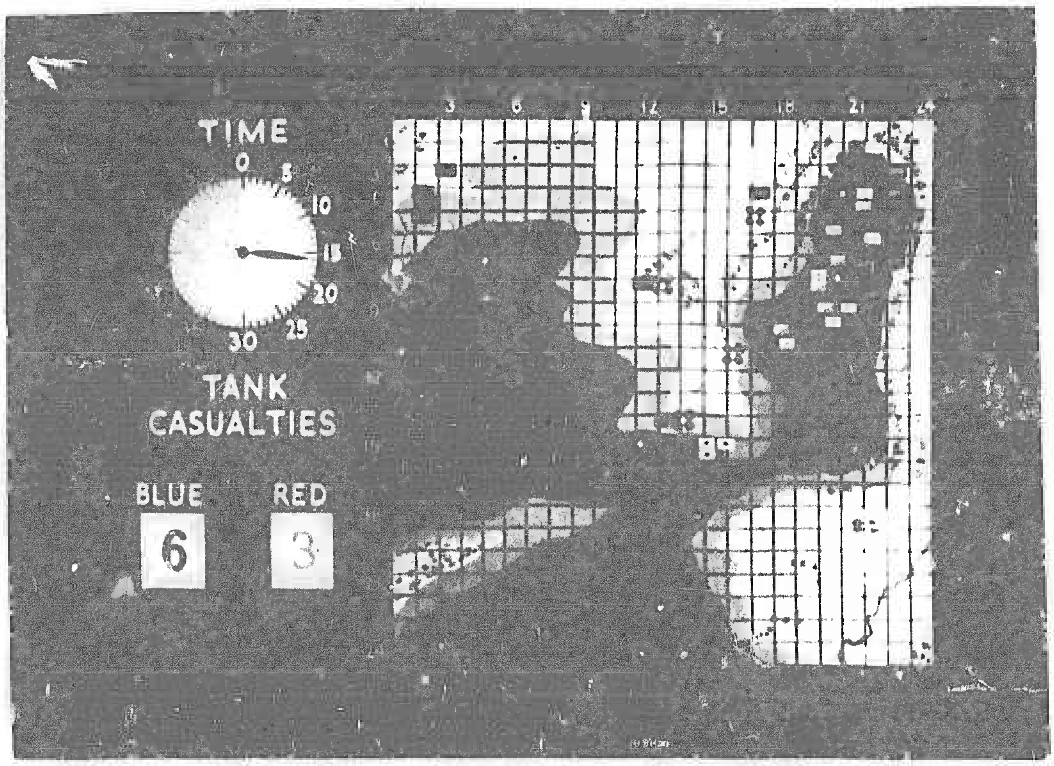


Figure 13

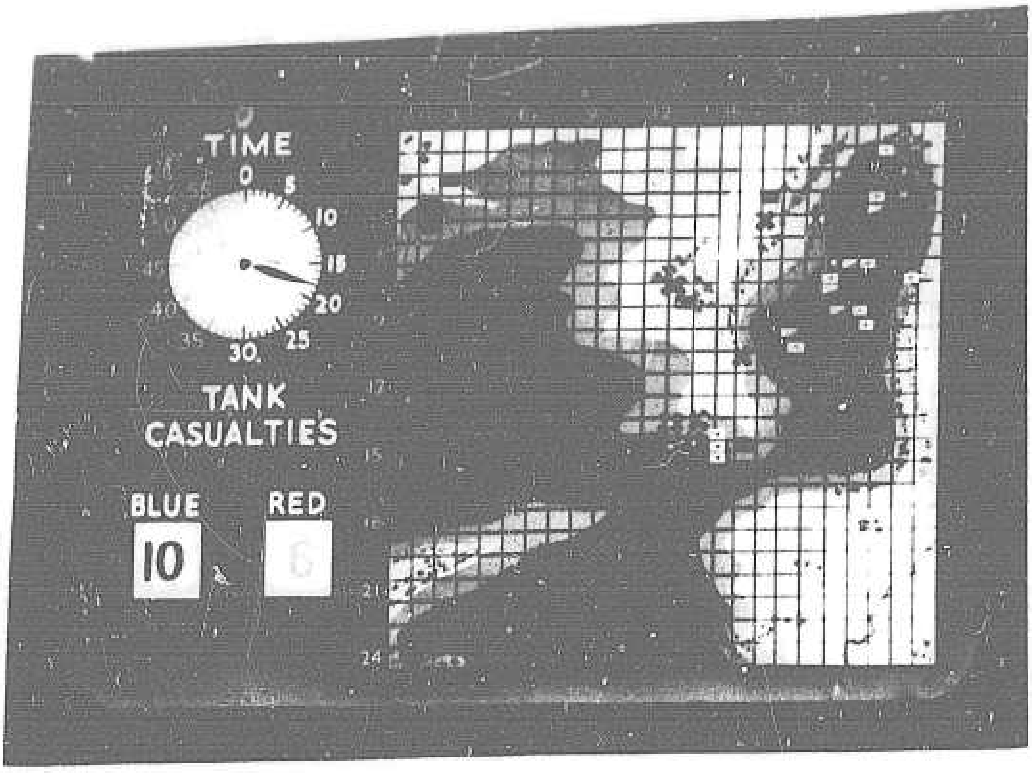


Figure 14

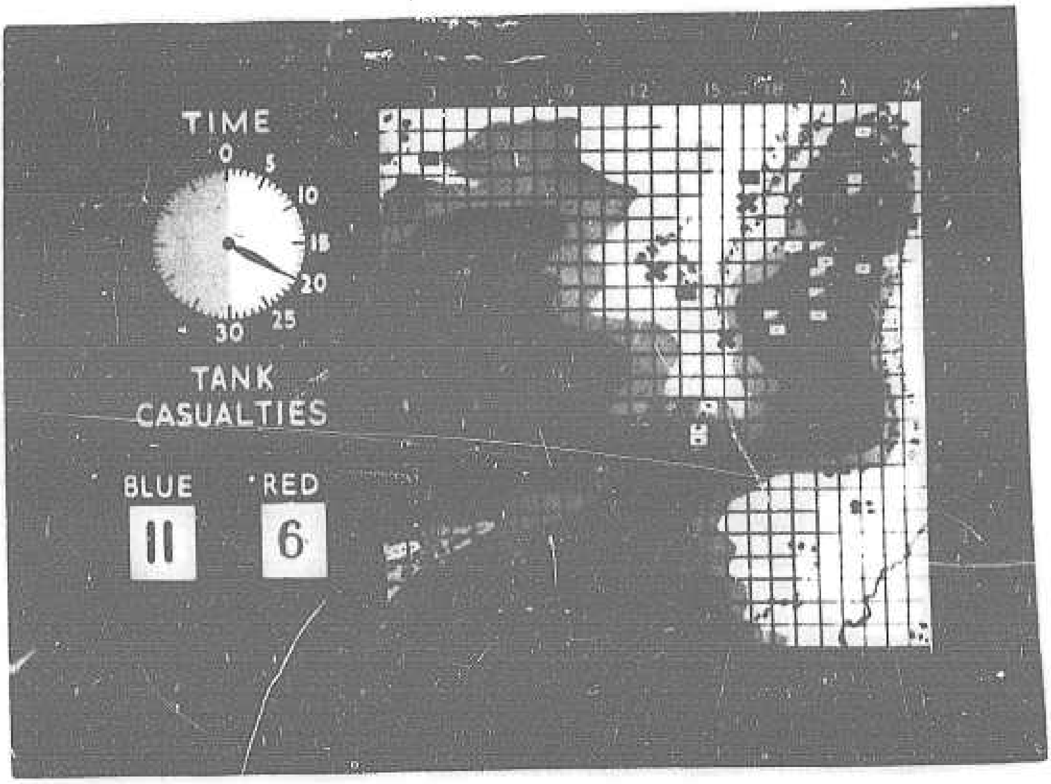


Figure 15

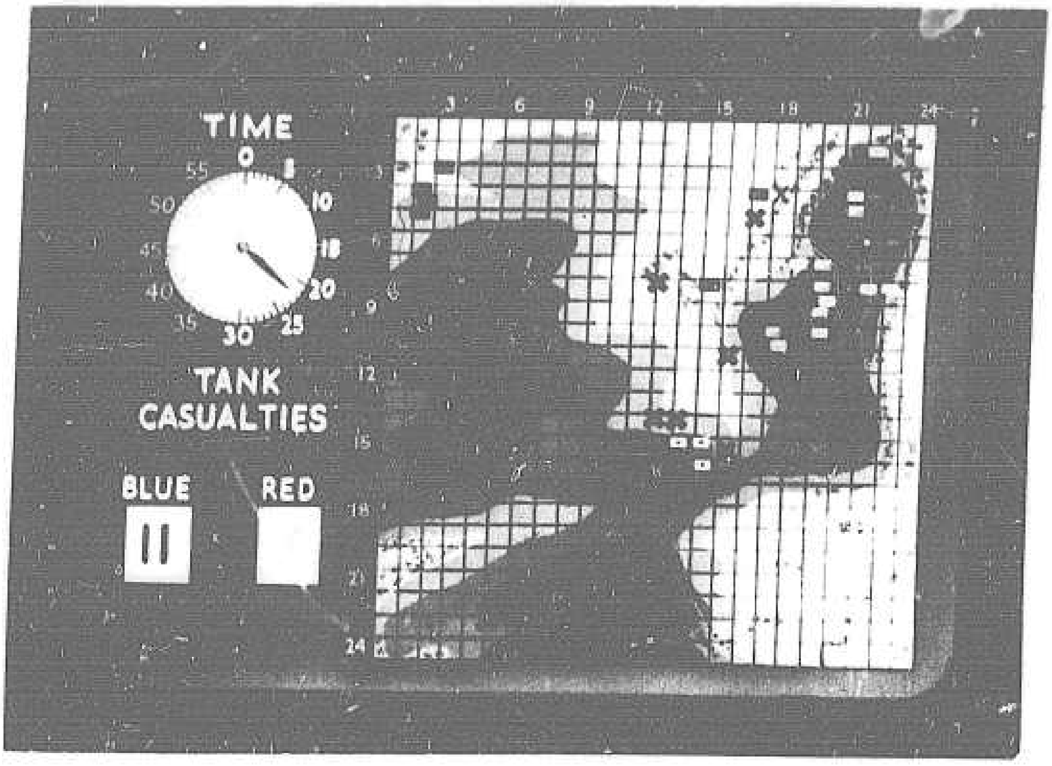


Figure 16

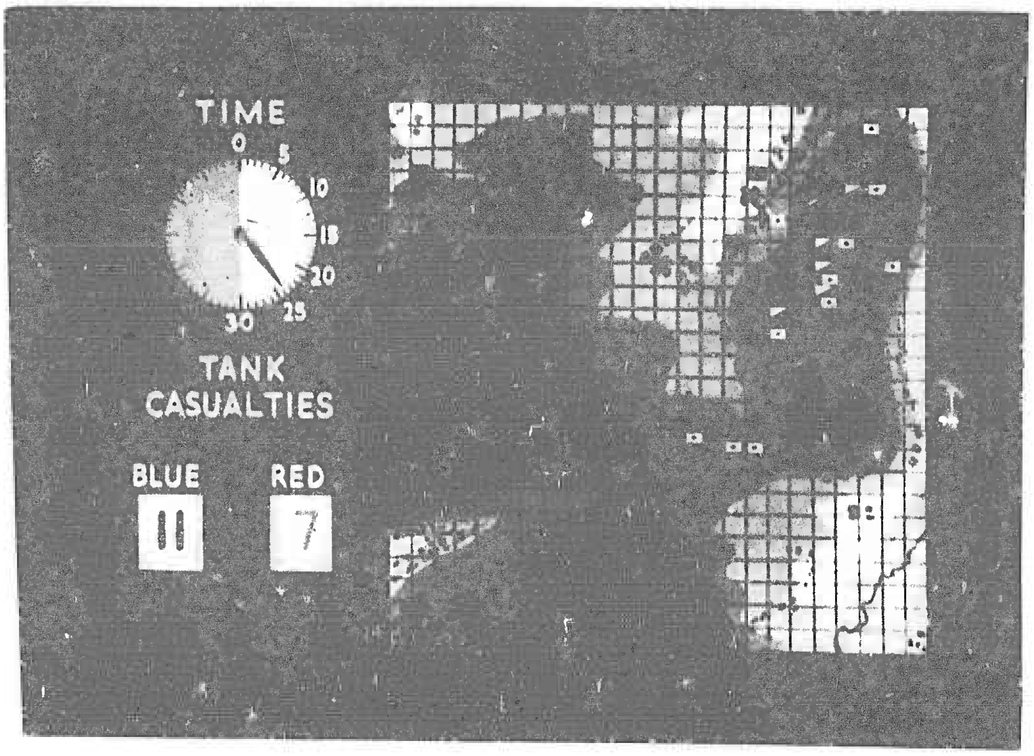


Figure 17

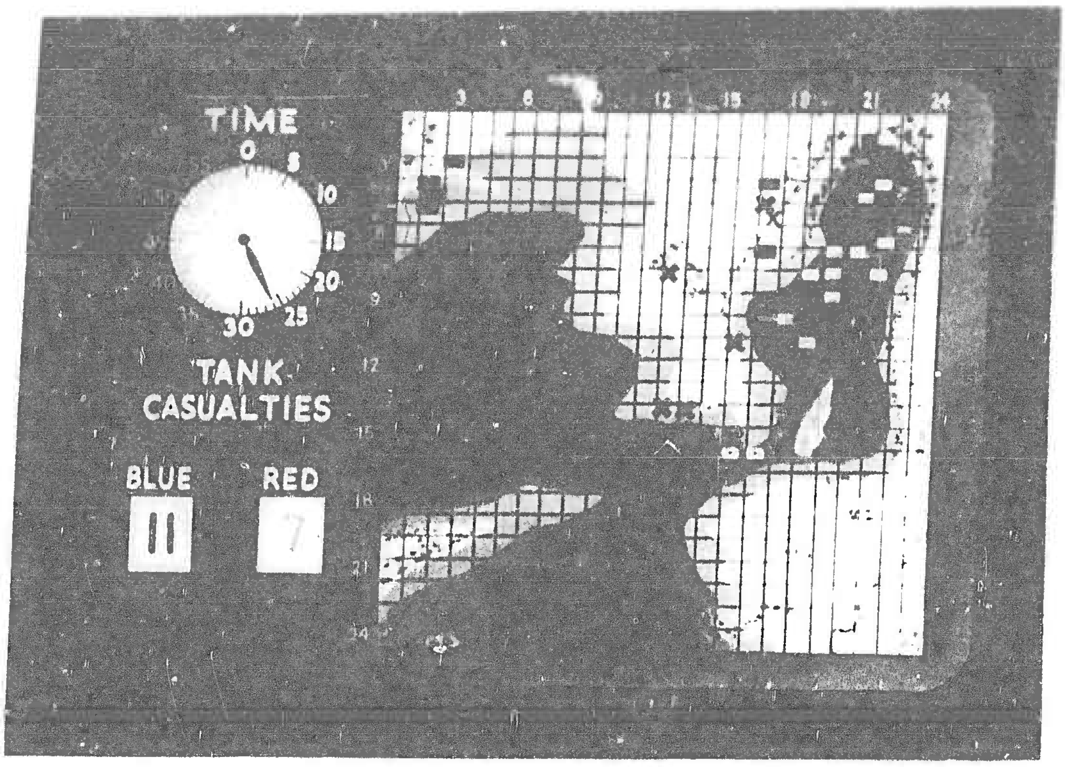


Figure 18

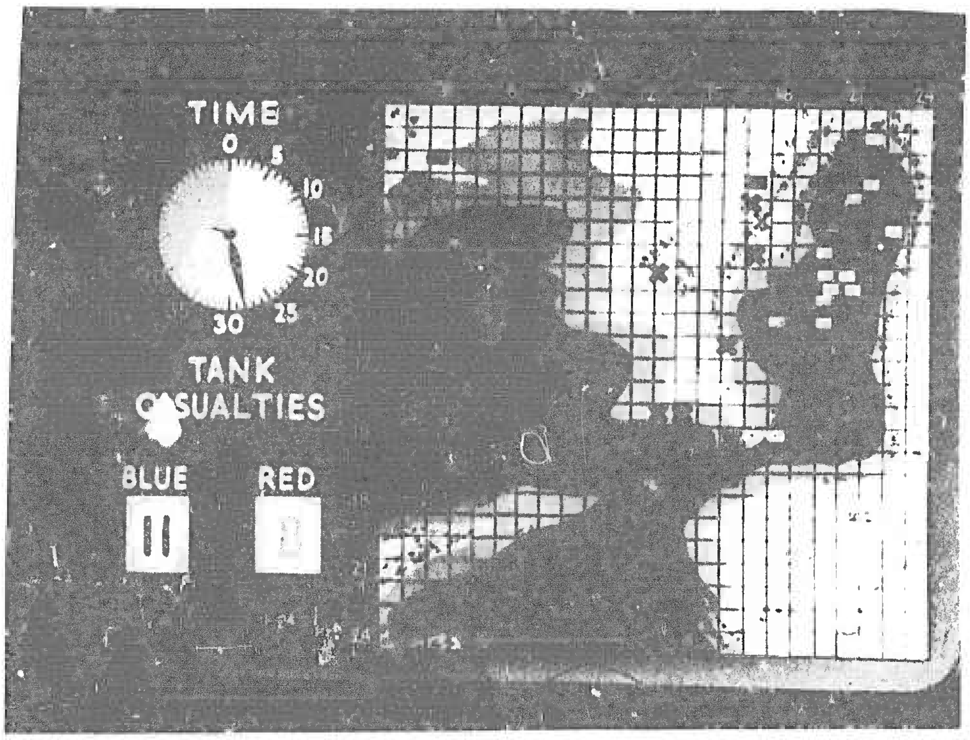


Figure 19

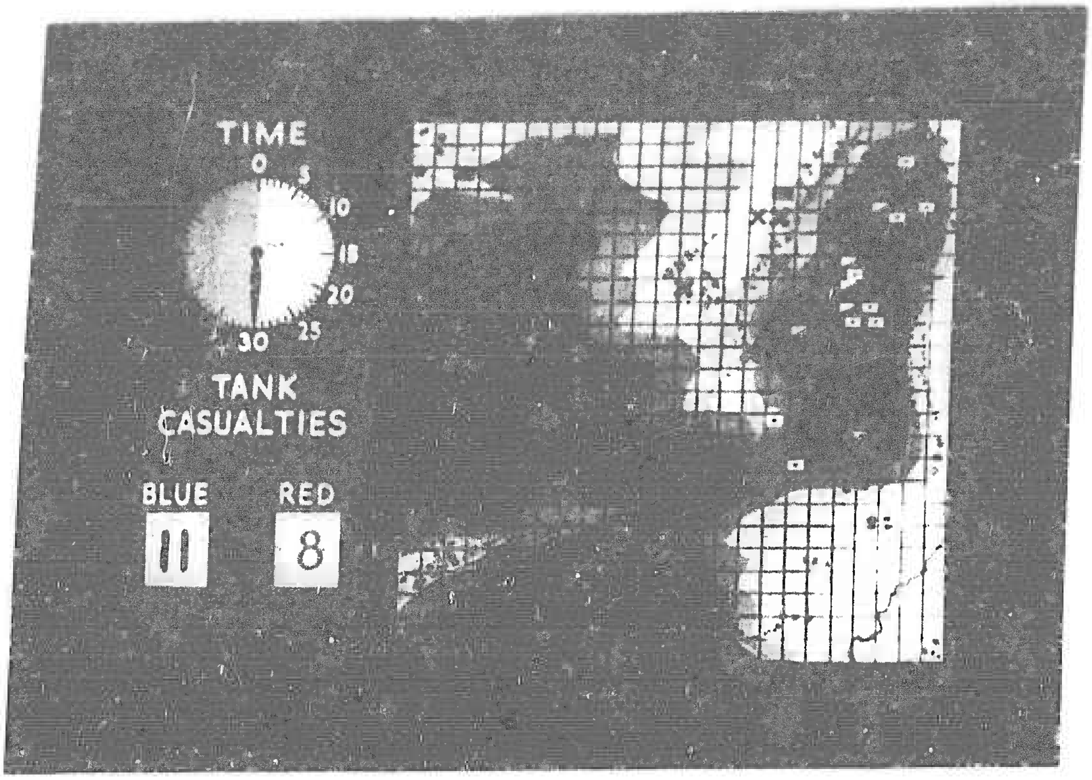


Figure 20

time to time fire upon selected enemy units. For the cases of greatest interest, single shot kill probabilities are sufficient to measure the performance of the gun. Of much greater interest, however, is simulation of the process of surveying the battlefield to discover enemy units, applying a priority system to select a target and the final decision to fire on the target. Figure 21 (V2861) indicates the intimate connection between the firing decisions by combat elements and the decisions to move. Note that the upper part of the figure indicates the unit will be given an option to fire only after it declines an option to move. Only in special circumstances is a unit first given an option to fire as in the lower part of the figure. In this special case, if the unit declines an option to fire, he is then offered an option to move. Thus the actual decision process carried out by each combat element at frequent intervals throughout the battle may be considered as involving a selection of one of four alternatives: (1) to move; or not move, and (2) to fire or (3) prepare to fire or (4) decline to fire. Clearly the move portion of this calculation, since it ordinarily comes first, is the more fundamental.

Terrain Quantification

Figure 22 (V3125) shows the complete history of one of the Blue tanks throughout the cartoon battle. It is apparent that the progress of the Blue tank towards the terrain objectives resulted from a series of discrete moves from one square to an adjacent square. The decision process associated with selecting a particular adjacent square as the next position to be occupied in the course of the assault is the most fundamental decision process carried out by the individual combat elements. In order to effect sensible simulation of the activities of a real tank, these moving decisions must be intimately related to the terrain features. Therefore, the average value of important terrain characteristics for each square must be identified, stored in the computer, and allowed to influence the move choice. Figure 23 (V771) indicates the level of approximation associated with squares of this size for the cartoon battle and the types of terrain features of interest. On the cartoon battlefield there were 24 x 24 or 576 squares. For each square there was stored the degree of average concealment to be associated with the vegetation on the square in 5 steps, varying between open fields to dense forest. In addition, for each square was stored the elevation to the nearest meter. Finally, the presence of selected terrain features was noted, such as swamps or roads.

CARMONETTE provides an increase in the number of squares to 36 x 36 or 1296, and a considerable increase in the information stored for such terrain features. The most significant additional terrain feature included in CARMONETTE involves terrain features we may term "vector" in nature. Thus Figure 23 indicates only the "scalor"

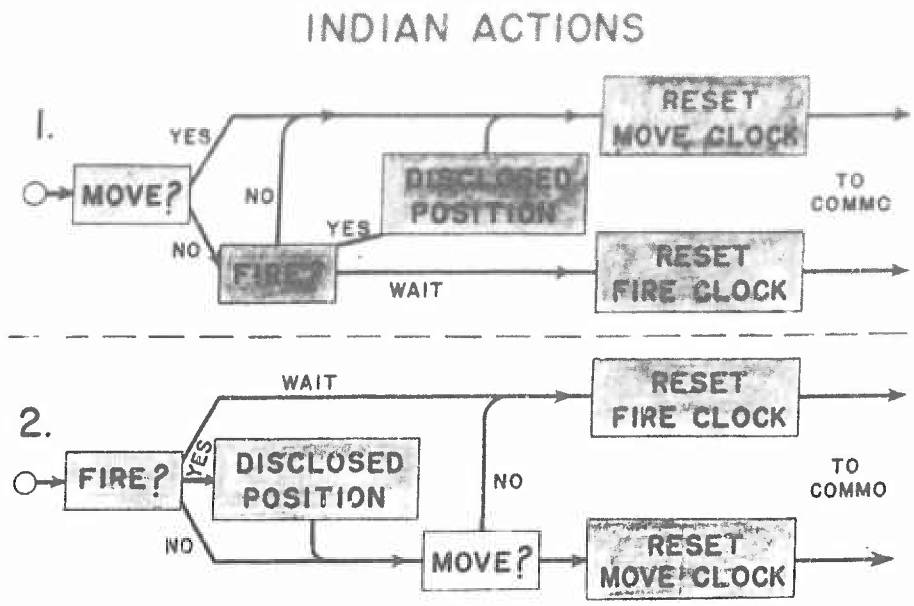


Figure 21

The calculation labeled "DISCLOSED POSITION" determines whether the act of firing has disclosed the firer's position to enemy units.

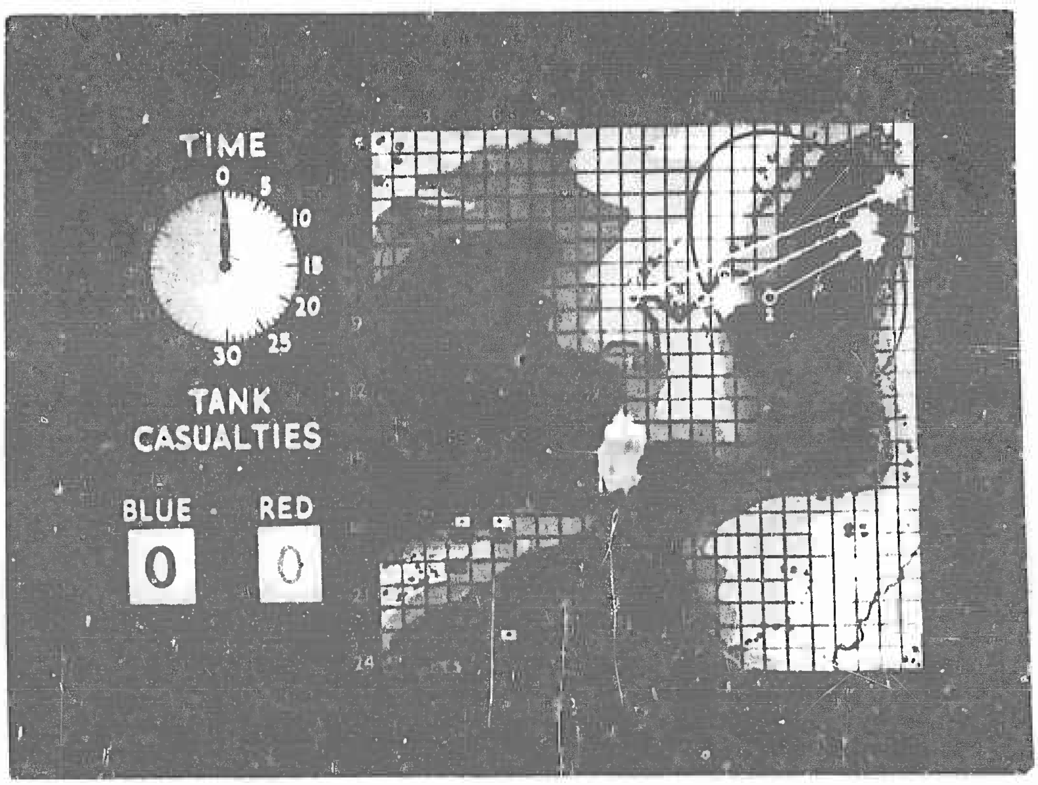


Figure 22

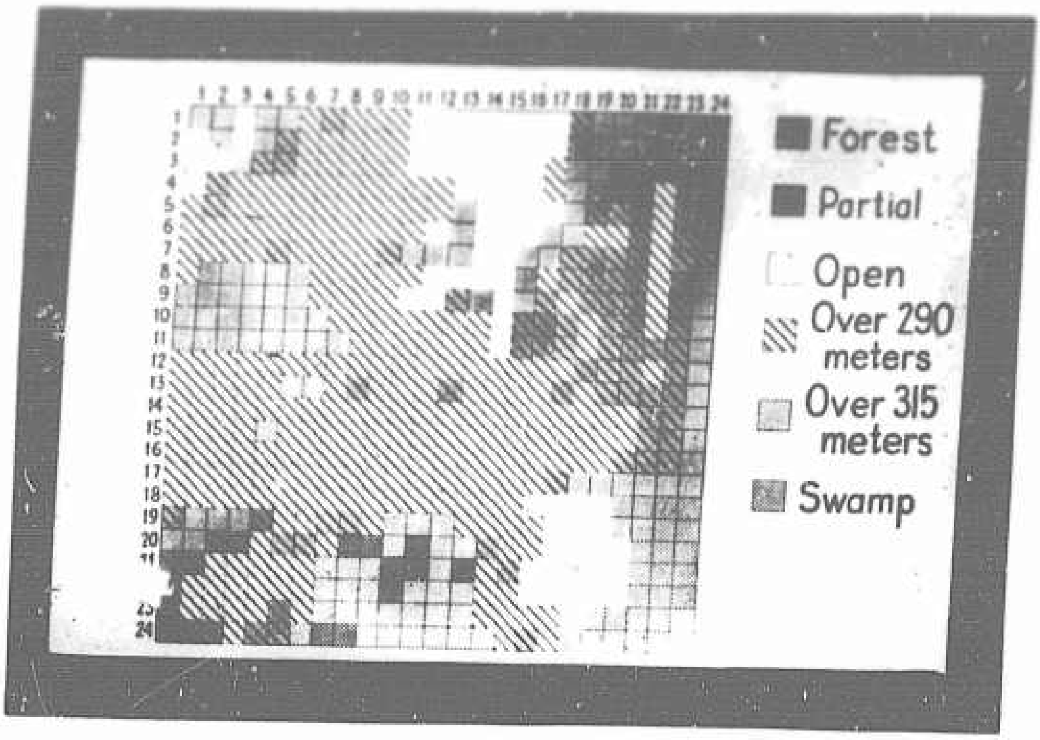


Figure 23

terrain characteristics of each square; that is, characteristics of the square alone which do not depend upon its neighbors. However, consider Figure 24 (V2634) which is a schematic representation using the 100 meter grid squares of a typical combination of improved and unimproved roads, a river, a bridge, and a river fording site. In this case it is clear that one cannot characterize the terrain features to be associated with the central square except by identifying the appropriate adjacent square. Thus an improved road leads from the central square to the west and to the northeast. An unimproved road leads to the southeast. No road leads to the northwest, the south, the southeast, or the east. Movement to the north is only possible if the vehicle is capable of fording the stream. Movement to the northeast can be interrupted if the bridge is damaged. Thus these terrain features have a direction and are properly termed vector terrain features.

Given such information about the terrain it is possible to cause a tank or other combat element to make each move dependent upon the terrain characteristics. As is indicated by Figure 25 (V782), the basic move decision involves a selection of one of the 8 adjacent squares as the next position to be occupied (or a decision may be made to remain on the present position). The general nature of the factors we should expect to influence this choice are listed. The first, exposure to enemy positions, and the third, desirable terrain, depend upon the quantification of the terrain just described. The move is likely to have a preferred direction (associated with the terrain objective) and, further, to be influenced by exceptional circumstances such as the knowledge that the tank is under fire or the inhibitions produced by the presence of friendly knocked-out tanks.

Before describing how these other features are to be handled in any detail, it is obvious that the computer move calculations can be made to depend on all terrain data stored for each of the adjacent squares in question. Note that the computer is capable of examining the existence of a physical line-of-sight between any and all units using the elevation stored for each square; and further, qualify the existence of such a line-of-sight by the influence of concealment afforded by vegetation, and thus obtain the degree of exposure to the enemy to be associated with each of the 8 adjacent squares in turn.

The essential calculation to be made involves summing the relative desirability from the point of view of the tank commander, of each of these squares in turn, using the types of data available, and then to select one of these squares on the basis of the weights so derived.

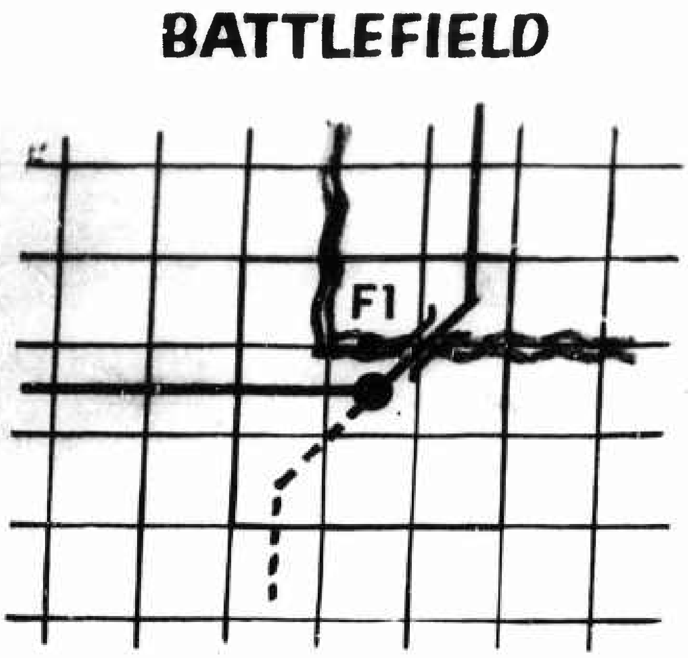


Figure 24

Vector Terrain Features. Mobility of element on central square is influenced by bridge, fording sight (F1), improved and unimproved roads.

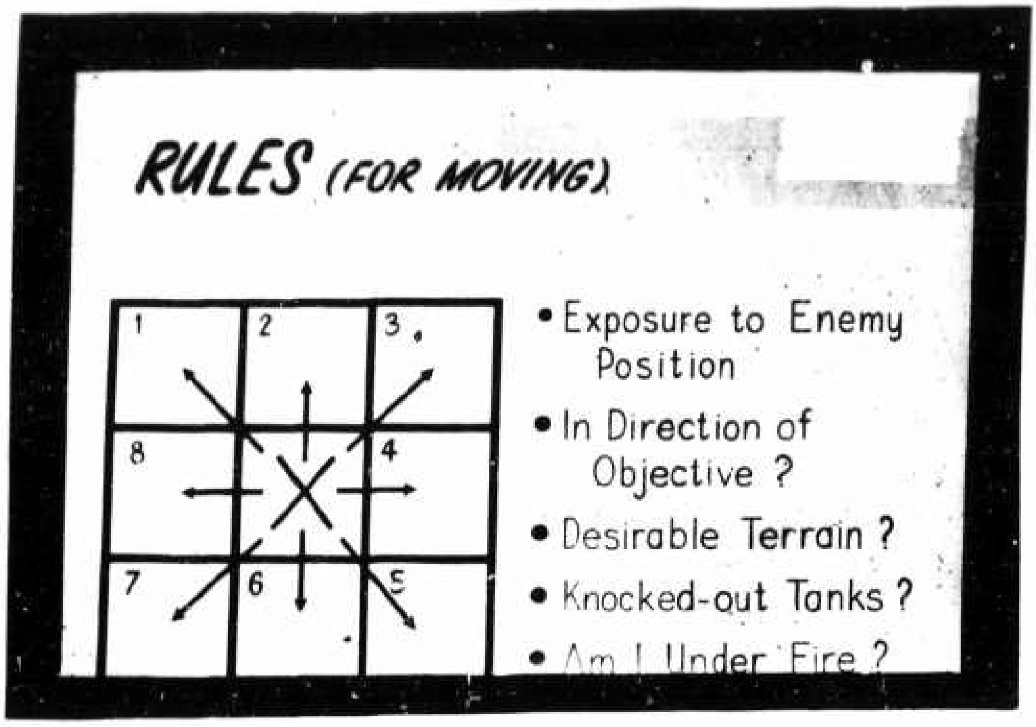


Figure 25

The elemental move decision is made repeatedly by each independent combat element in light of the battlefield situation.

Before discussing in detail the specific procedure used in CARMONETTE for this weighting process (a matter of secondary interest) let us consider the more basic problem of what will be done with the weight—that is, the way in which one square will be selected. Figure 26 (V3221) graphically illustrates this point. In fact, CARMONETTE proposes to use the weights developed by the scoring process, no matter how they are derived, as giving the relative probability that the tank will choose a particular square. This calculation will therefore be of the "Monte Carlo" type much used by applied mathematicians since World War II. This interpretation of the rating process has far-reaching consequences since it introduces the play of chance into the battle calculations from the very beginning. Therefore, the results of any particular calculation have no general significance. Each battle must be repeated a number of times sufficient to generate the usual statistics associated with distributions.

Some Trial Battle Results

Figure 27 (V775) is a scatter diagram of the results[2] of 50 repetitions of the "cartoon" battle which differ only due to the play of chance. The diagram indicates no strong correlation between the Blue tank losses and the Red tank losses. Figure 28 (V3219) shows the actual distributions separately—the average Blue losses being 10.4 tanks per battle and the average Red losses being 7.1 tanks per battle. Both distributions may be considered to be samples drawn from a Gaussian population within the usual confidence limits. Figure 29 (V3220) indicates the convergence of the mean with increased numbers of battles. The difference between the mean Red tank losses and the Blue tank losses are statistically significant at a very high level. For this series of battles, therefore, 50 repetitions is an adequate sample size to determine "winners" by comparing mean losses for all except the most marginal cases.

To demonstrate the sensitivity of the model to changes in the performance characteristics of a weapon system, a second series of 50 battle calculations were made. In this case, the 17 Blue tanks were replaced by 17 hypothetical light tanks, with a doubled cross country speed and the rate of fire, but substantially reduced armor thickness and gun power. All other factors were unchanged. Figure 30 (V1187) gives the frequency distribution of tank losses for this second series of battles. Here the mean Blue tank losses were less than the mean Red tank losses at a very high level of confidence.

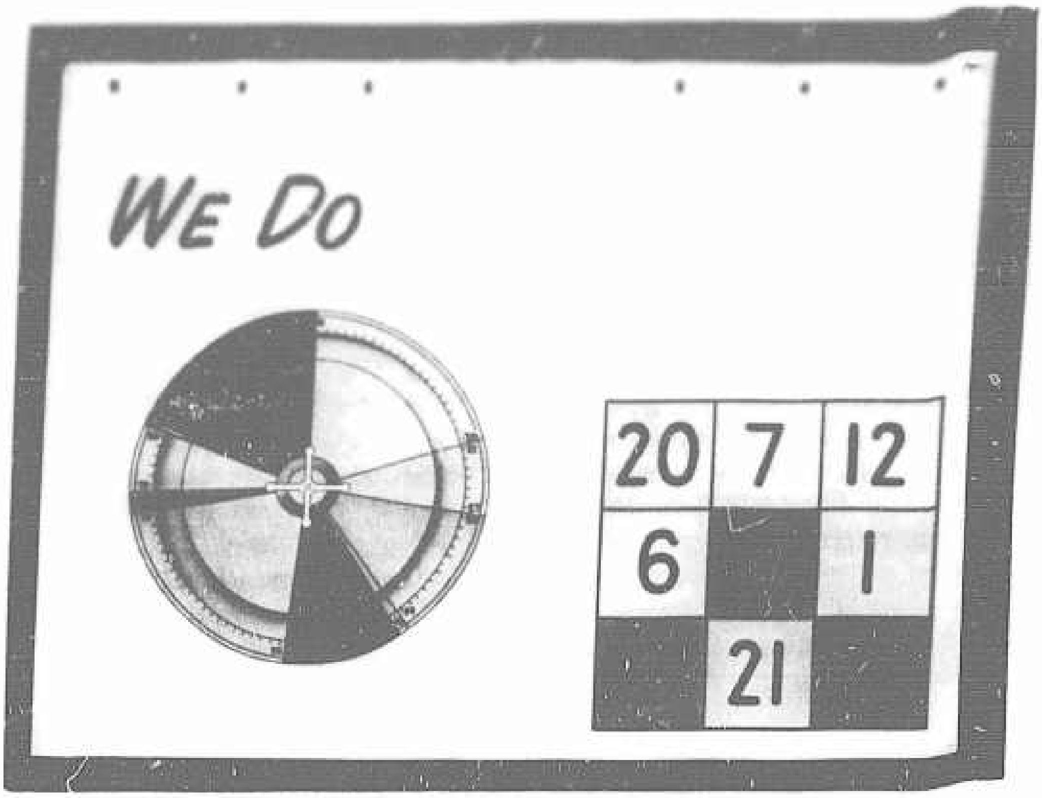


Figure 26

Sample weighting factors inscribed in each of 9 squares are associated with probabilities by comparison with roulette wheel. A single spin of wheel then "selects" next square and thus determines movement of tank.

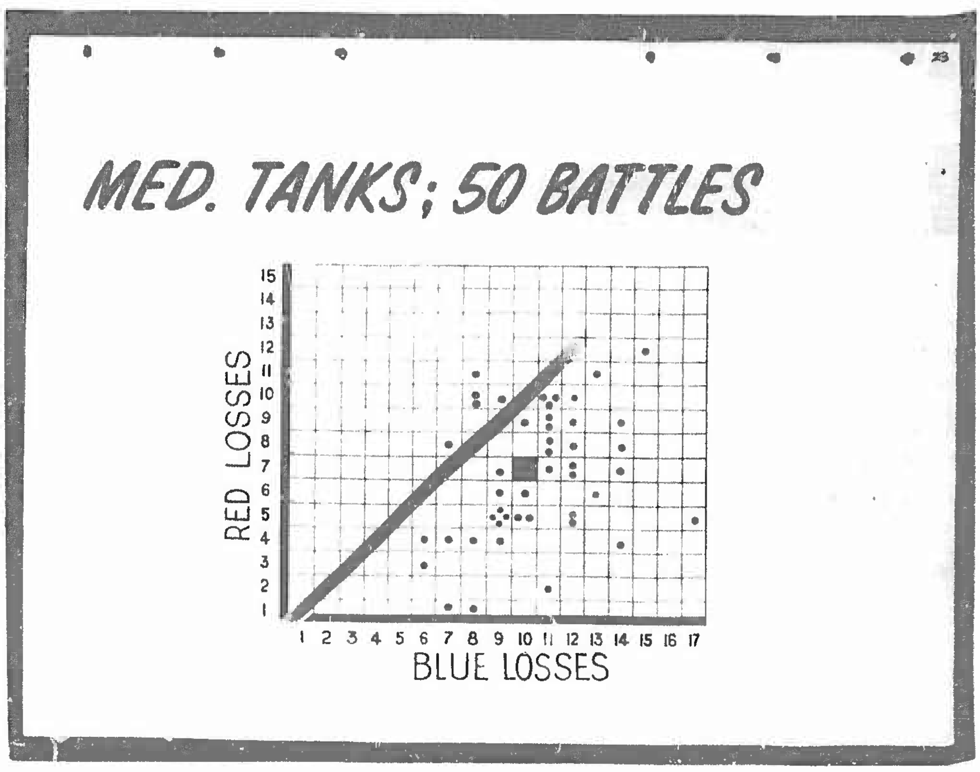


Figure 27

Scatter diagram of casualties from calculations. Variation in outcome depended only on the operation of chance.

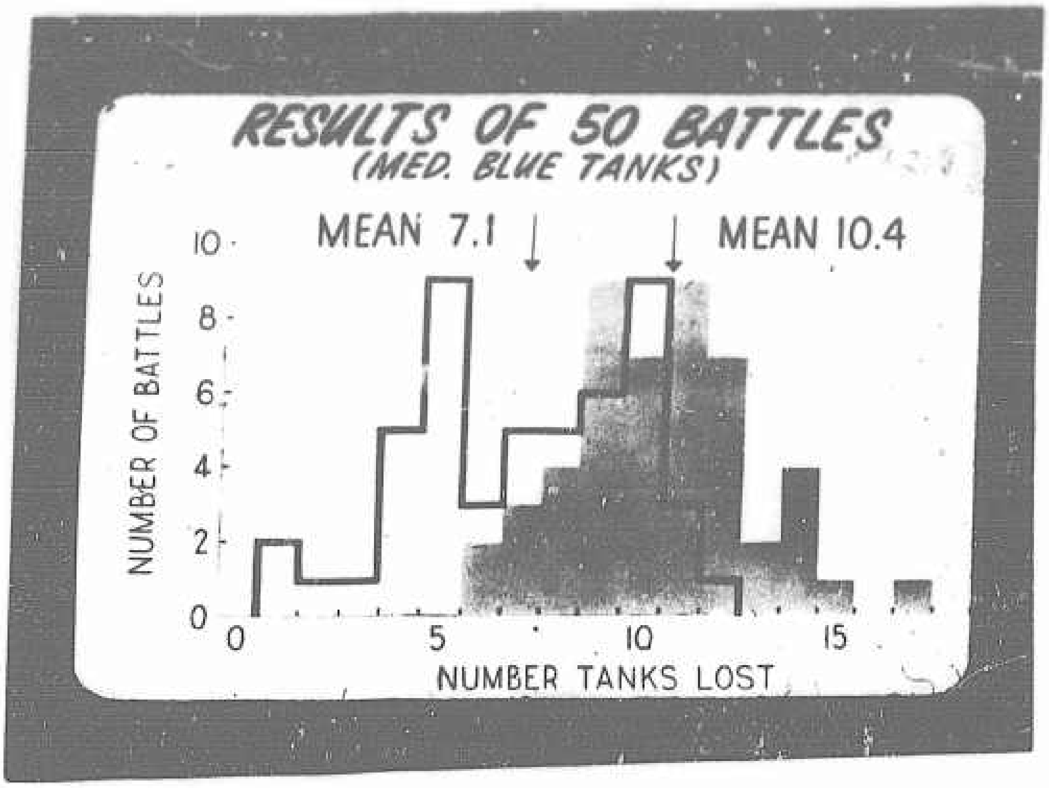


Figure 28

Blue casualty distribution indicated by solid area; Red casualty distribution indicated by outline.

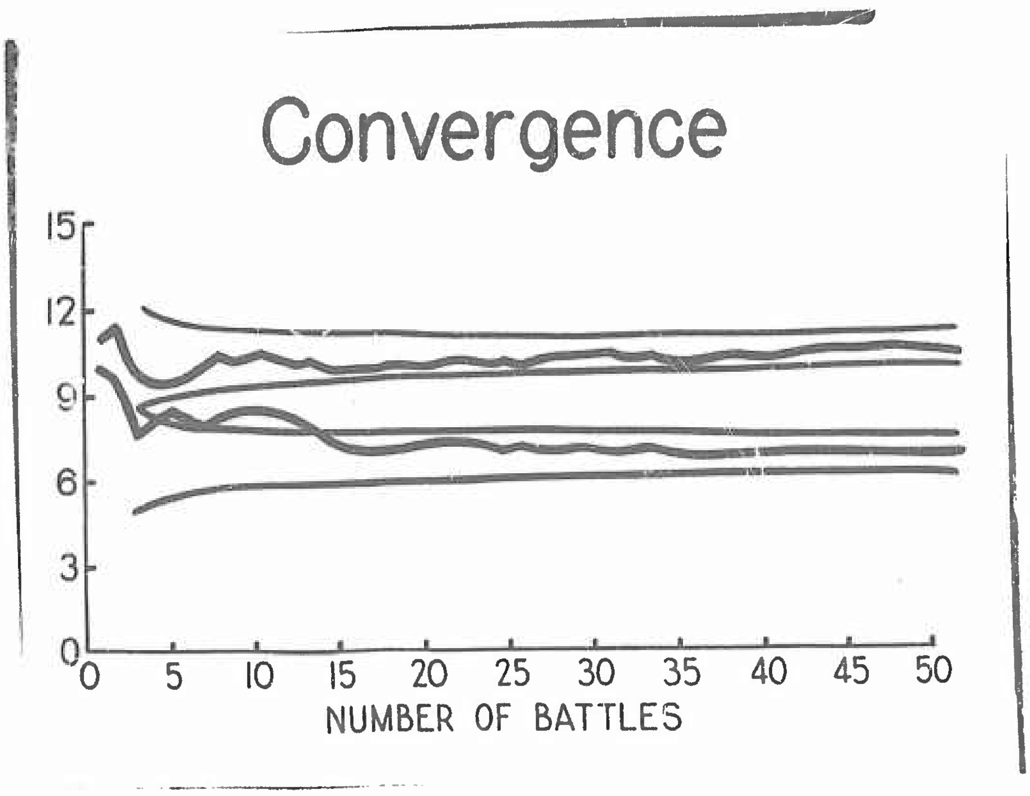


Figure 29

The upper curve indicates variation in Blue's cumulative mean casualties. The lower refers to Red. Also indicated is the standard deviation of the mean computed from the sigma of the distributions shown in Figure 28.

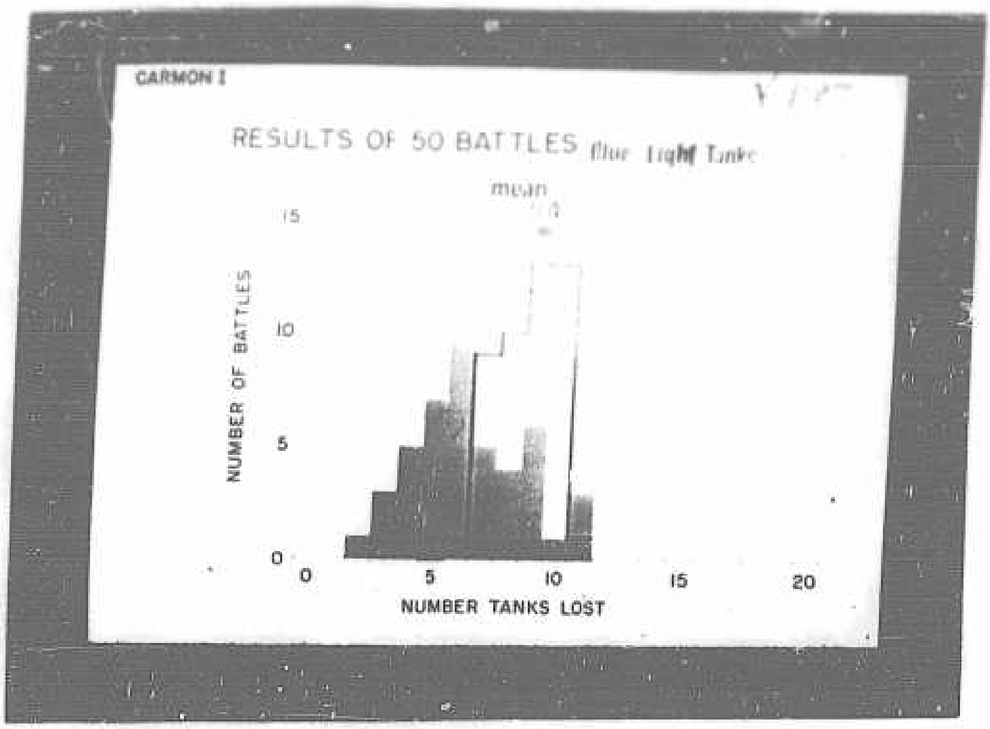


Figure 30

Blue light tank casualty distribution is shown by solid area; Red distribution by the outlined area.

Significance of Probabilistic Model

It is evident that the above interpretation of the ratings as probabilities carries with it a high cost since it will therefore be necessary to repeat the calculations many times so as to determine the distributions. Let us examine the argument in support of this choice as against the simpler alternative of causing selection of that square with the highest rating to be a certainty. I offer three arguments in support of this choice.

Perhaps the most fundamental reason relates to the preference for a system which permits, at least in principle, direct verification by experiment. Thus, if it were desired to conduct a field experiment in which a representative group of tank commanders were requested, in identical circumstances, to identify the square to which they would move, then we can be sure that the group would frequently demonstrate a variation in their choice. Therefore, the experimental raw data would surely be a probability distribution, and the model must provide for its use in that form. Clearly an experimental program designed to determine such data for a variety of battle situations and terrain types would be of tremendous size and cost. Yet the model must certainly be compatible with the nature of the experimental evidence which may become available as a matter of principle and practice.

A second reason for the probabilistic interpretation is that in a sense it automatically compensates in a simple and straightforward way for the uncertainties bound to be associated with any particular rating process used. Thus, if the rating process used were to produce roughly equal scores for several squares, interpretation of these scores as relative probabilities avoids what must surely be an arbitrary and unsatisfactory selection of the one with a trivial superiority.

A third reason which supports a probabilistic interpretation relates to the consequent possibility of investigating directly the sensitivity of a mechanical weapon system (with which there may be associated only small uncertainties) to variations in component performance resulting from the human factors which complicate the analysis of any real weapon system. In effect, the probabilistic interpretation is more consistent with the performance of man-weapon combinations and permits a more direct attack on the problems of such combinations than would any system which excludes probability.

We conclude that though the price is high, here and elsewhere throughout CARMONETTE, the preference will be for similar probabilistic interpretations.

The Terrain Feature Rating Process in Detail

Now that we have discussed the probabilistic character of the model, we will return to a description of the details of the weighting process. Figure 31 (V2853) indicates that the final rating (W) for each square will be taken as the sum of 6 distinct components. And that each component is the product of one factor, the "L" values, to be associated with the battlefield, and a second factor, the "a" values, to be associated with value judgments or command decisions by the unit commanders. Ultimately the "a" values will provide the means by which individual actions may be assembled into a sensible battle reflecting the plans and will of the commander.

The L values or "facts" of the battlefield are each associated with a distinct class of facts, listed in Figure 32 (V2869). The intent is to use the terrain features of the battlefield in conjunction with each man's knowledge of the disposition of the enemy and the characteristics of his own unit in the construction of these L values. Notice that L_1 and L_2 comprise an assessment of the desirability of a square in terms of its defensive potential. And that L_3 and L_4 provide the basis for an assessment of the desirability of each square from an offensive point of view; that is, the speed with which he can move across the square and the danger resulting from exposure to the enemy in the process. L_5 judges the square according to whether or not movement to the square will result in breaking formation. Each of the squares is also scored on the degree to which movement to that square is in the preferred direction. Referring back to Figure 31 we may now observe the significance of the "a" coefficients. Their purpose is to adjust the influence of each of the first five components relative to the influence of the sixth component. Thus, we see that if a particular coefficient is set to zero, as the extreme case, the tank commander will no longer allow his movement to be influenced by that factor. For example, bold, even reckless, attacks will be associated with small values for the a_1 thru a_4 coefficients, with the result that units will tend to take the most direct route to the terrain objective. Cautious, fast moving attacks will be associated with high values for a_3 but lower values for a_1, a_2, and a_4. Extremely cautious attacks would require high values for all the coefficients.

As a general rule the L values to be associated with a given combination of terrain features and other battle parameters are to be stored in the computer in the form of extensive function tables. Recourse to formulae will be made only after the memory capacity of the computer is substantially exhausted by the tables.

SQUARE WEIGHTS

$$\boxed{W = a_1 L_1 + a_2 L_2 + a_3 L_3 + a_4 L_4 + a_5 L_5 + L_6}$$

Where

$L_1 \ldots . L_6$ = Battlefield

And

$a_1 \ldots . a_5$ = Adjusted by Chief to meet changing circumstances

Figure 31

Square Weights

[redacted]

where

$L_1 \cdots L_6$ = Battlefield

and

$a_1 \cdots a_5$ = Adjusted by Chief to meet changing circumstances

Figure 31

Battlefield

$L_1 \equiv$ cover & concealment (defense)

$L_2 \equiv$ man made objects

$L_3 \equiv$ trafficability (offense)

$L_4 \equiv$ fields of fire

$L_5 \equiv$ dispersion

$L_6 \equiv$ terrain objective

Figure 32

To illustrate the connection between various battle factors and these L values, I will discuss the construction of the L_4 value, "Fields of Fire." The L_4 value itself is related to a number of battle parameters indicated by Figure 33 (V2860). This is the most complex of the L value components since it includes the essential cross terms with the other components. It can take on both positive and negative values corresponding to a desirable or undesirable combination of circumstances. The numerical value of the right most bracket is proportional to the threat associated with a particular square by virtue of the existence of enemy units who can observe movement on a square so far as is known or suspected by the tank commander. The three components of this bracket (L_{41}, L_{42}, L_{43}) correspond to different degrees of certainty in the mind of the tank commander as to the existence and type of these enemy units. The coefficients b_1 and b_2 degrade the influence of the less certain information. Function tables involving type of enemy unit, range, type of friendly unit, and similar factors yield the L_{41}, L_{42}, L_{43} values. Note that the L_{43} value is the most speculative of the 3 classes of combat intelligence since it refers to enemy units whose presence is only inferred from the excellent observation provided by the terrain feature if the enemy were to occupy it. Therefore, a large value for the coefficient b_2 corresponds to an exceedingly cautious tank commander.

The left most bracket on the right hand side of the L_4 equation enhances or degrades the influence of the right most bracket according to the degree of cover, concealment, and trafficability afforded by the square. These are the cross terms with the other L value components. The intent is to qualify the threat implied by large values of the right hand bracket depending on whether the local cover will permit enemy observation of movement within the square.

Combat Intelligence

The previous discussion generated a requirement for classifying the tank commander's knowledge and opinion of the enemy's type and position. Figure 34 (V2865) lists the general classes of such knowledge. It ranges from precise and accurate knowledge of type and position through general knowledge of position and an estimated type (may be inaccurate) to a completely erroneous belief as to the position of an enemy unit. CARMONETTE provides for the generation of distinct knowledge and information for each separate unit on the battlefield.

There are three sources of information of an individual's knowledge about the enemy: (1) a direct and continuous survey of the battlefield making use of the UMPIRE routine, (2) a special calculation

Fields of Fire

$$L_4 \equiv [C_1(L_1 L_2) + C_2(L_3)][L_{41} + b_1 L_{42} + b_2 L_{43}]$$

where $L_{41} \equiv$ Class 1 & 2 Combat Intelligence

$L_{42} \equiv$ " 3 " "

$L_{43} \equiv$ Good Firing Positions

$C_1(L_1 L_2) \equiv$ Cross terms with cover and concealment factors

$C_2(L_3) \equiv$ Cross terms with barrier

$b_1 b_2 \equiv$ Doctrine and/or training coeff

Figure 33

Combat Intelligence

1. Known—Identified Enemy
2. Position Known—Type Estimated
   - a. MG (inf)
   - b. AT gun
   - c. Tank
   - d. Inf.
3. Position in Error
   - a.-d. as above
   - e. "Identified"

Figure 34

associated with the likelihood that the firing of one's weapons may reveal one's position to enemy forces and (3) messages received through the communications system.

Umpire Routine

The umpire routine at regular intervals throughout the battle considers the mode of behavior of each combat element on the battlefield in turn. The result of such consideration is a list of those enemy units the combat element may be considered as having under observation. The calculations make use of function tables with the dimensions of range, type of unit being observed, its general activity, its previous exposure history, and the activities of the observer. This survey of the battlefield will be programmed to be completed once each 2 seconds of battlefield time.

Firing; Disclosed Position Routine

Each individual's knowledge of the enemy may also be added to immediately after an enemy unit fires its weapons (Figure 21). Again the calculation makes use of function tables with substantially the same dimensions as those used by the umpire routine. Data acquired during a recent field experiment, PINPOINT, will be used for these calculations.

Communications System

When a unit comes into the possession of new information (ordinarily information about enemy position and type), he may, depending on established communication procedures, transmit this information to selected friendly units. Figure 35 (V2863) indicates in its upper half the general steps involved in the transmission of this information, and in the lower half gives a compact representation of the combat elements which may communicate directly with one another. Interpretation of this form, which is based on the binary number system used in the computer, is straightforward. Each column is associated with a particular combat element including the unit commanders. Each row indicates by 1's in the appropriate column that combination of combat elements which may communicate with one another. For example, the first column stands for the company commander, the second column stands for the commander of the assault group, the thirteenth column stands for the commander of the base of fire group, and the thirty-second column stands for the commander of the supporting artillery platoon.

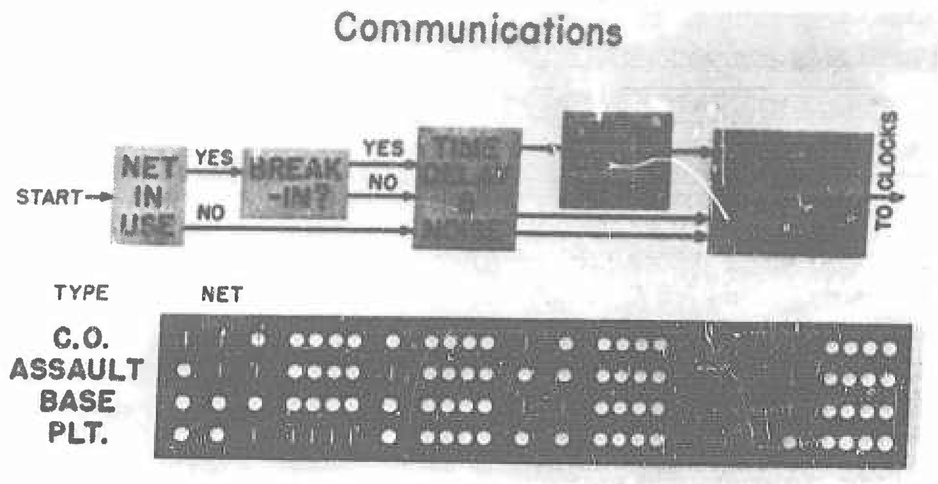


Figure 35

This illustrates the method of simulating the communication system. The upper flow diagram indicates the principal steps in the calculation. The lower half of the figure shows schematically by each row the members of a particular communications net.

The first row, therefore, indicates that the above named individuals comprise one communication net. This particular means of representing information facilitates calculations by the computer.

<u>Infantry Units</u>

So far as their movement is concerned, the infantry squads (or in special cases platoons) move as a unit from square to square. However, the weapon system is complex, hence the different types of weapons must be treated distinctly. In CARMONETTE each member of the fundamental infantry unit (usually the squad) is treated separately so far as weapons fire, ammunition stocks, and casualties are concerned. Figure 36 (V2868) indicates the compact form used to store data indicating the types of squad members. Each column corresponds to a particular member of the squad as is indicated on the diagram. Again this scheme for storing information is designed to facilitate computer calculation since it depends on a binary form which is used for all information retained by the computer.

A TACTICS ROUTINE FOR COMMAND DECISION

We have described a model for the simulation of an ordered sequence of combat actions by the combat elements on each side. However, we have not described a mechanism that will insure a sensible sequence of actions.

It will be recalled that a number of parameters and coefficients have been introduced in the course of the discussion thus far which can profoundly alter the character of these calculations. These include (1) the "a" coefficients (Figure 31) which have a very strong influence in the way in which combat units react to the situation around them in their moving deliberations; (2) the location of the terrain objective which by its position relative to the enemy may correspond to such extremes as attack or retreat; and (3) the priority system to be associated with the selection of targets which includes the option to decline to fire. Evidently if the sequence of actions is to be arranged in a sensible way we can most easily do so by appropriate adjustment of these general parameters. In other words, we have the <u>means</u> of implementing a sensible plan of battle if we can provide for the <u>generation</u> of a sensible plan of battle. The TACTICS routine has this as its primary function.

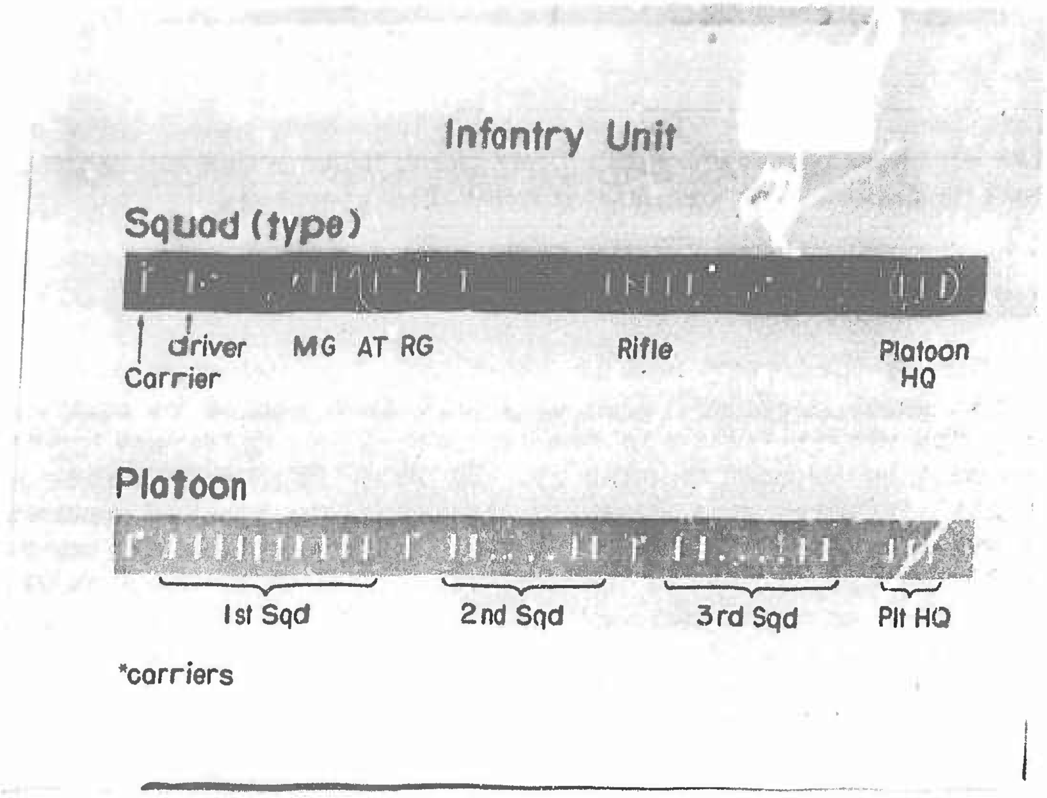

Infantry Unit
Squad (type)
driver
Carrier
MG
AT
RG
Rifle
Platoon HQ
Platoon
1st Sqd
2nd Sqd
3rd Sqd
Plt HQ
*carriers

Figure 36

In effect the TACTICS routine is simulation of the deliberations of a commander as he generates a plan of action sensibly related to the course of battle up to that point.

Hypothetical Battle

To clarify the logic of the decision process let us begin by considering the fortunes and misfortunes of a small armored formation as it strikes deep into enemy territory. Figure 37 (V2706a) indicates the first phase of an engagement forced on a Blue company commander. He is proceeding in column along the road towards the northeast when he is brought to a halt by the fire of a powerful antitank gun in position just to the east of the bridge. We may imagine that the Blue commander surveys the situation and within a few seconds issues orders for an attack as indicated: the first and third platoons in the column to take up covering positions; the second platoon to flank the Red antitank gun on its left; the third platoon is to send out a small patrol to investigate the enemy's right flank. The fourth platoon takes up a defiladed position to support the assault by indirect fire. The second phase of the battle develops when, as indicated by Figure 38 (V2706b), the assault platoon comes under the fire of a strong enemy force believed to be in company strength. Simultaneously the patrol crossing the river to the north discovers only light resistance in platoon strength. The reaction of the Blue commander is to place a small yield nuclear weapon on the Red position, Figure 39 (V2706d), and withdraw the forward elements of the assaulting platoon back across the river to take up a covering position. The left platoon then is designated the assaulting group, Figure 40 (V2706e).

During the hypothetical action just described, the Blue company commander twice made a major tactical decision drastically influencing the detailed combat actions of all of his subordinates: first when the units deployed from their column formation to attack the enemy's left flank; second when the Blue company commander halted this attack, caused the use of a nuclear weapon, and ordered a new attack on the enemy's right flank. The TACTICS routine is required to simulate such major command decisions.

If we had inspected the above battle in more detail, we would have noticed a larger number of less drastic decisions by subordinate commanders, decisions however having the same general character and consequences as the company commander's deliberations. The TACTICS routine must simulate these decisions as well.

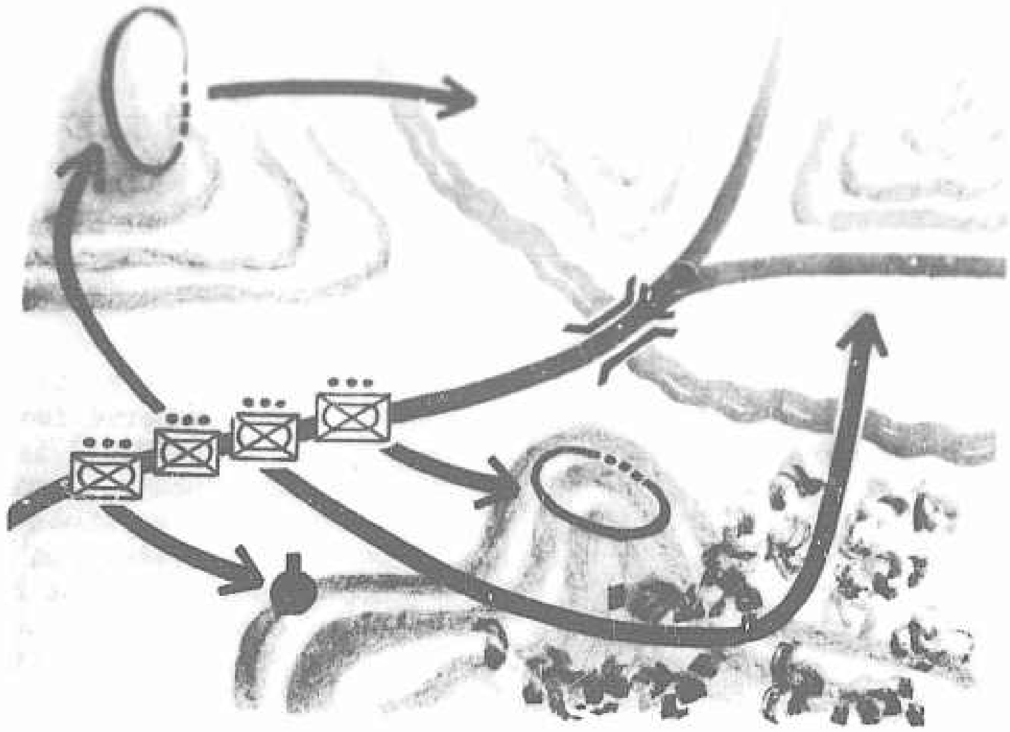


Figure 37

First assault plan implemented by commander.

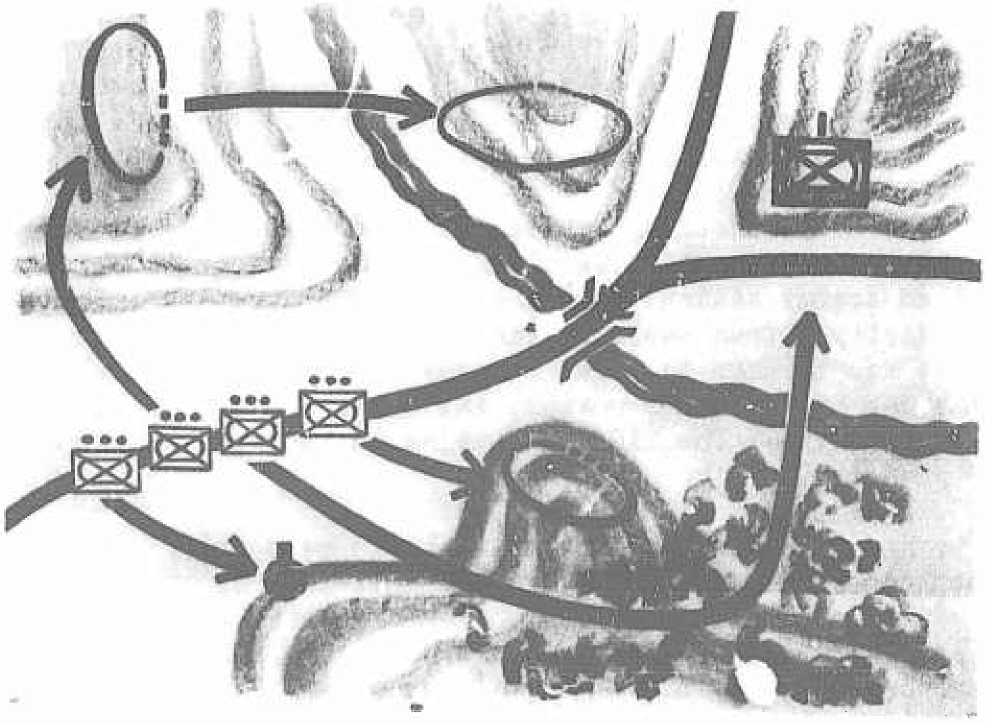


Figure 38

Contact intelligence generated by maneuver.

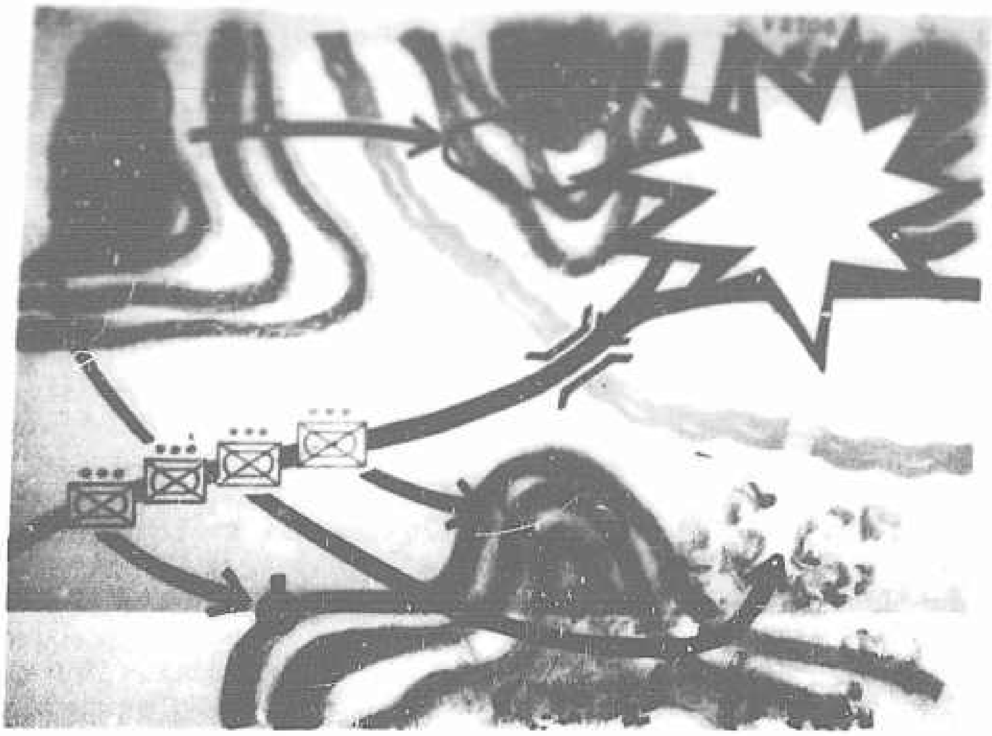


Fig 39 Nuclear fire is placed on enemy concentration

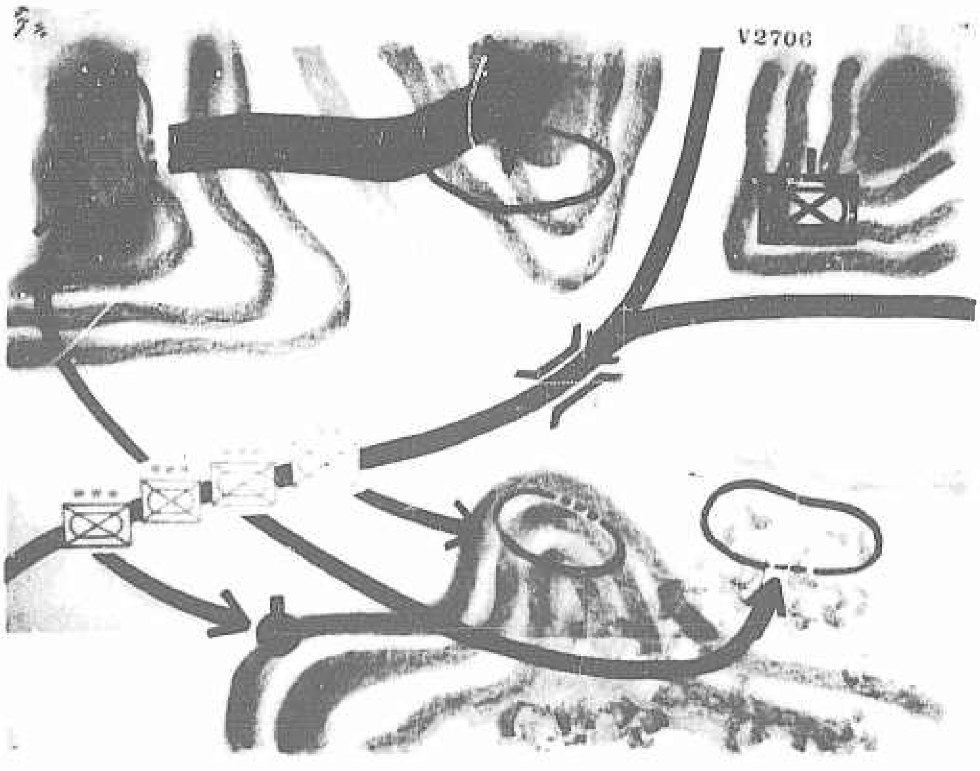


Fig 40 Revised assault plan

Clearly either of the attack plans selected by the company commander in the preceding example could be implemented by the mechanisms already described for CARMONETTE by appropriate choice of the numbers. Further the CARMONETTE mechanisms already described provide for explicit description of the known or suspected enemy positions which triggered the company commander's decisions.

The Logic of Decision Process

Let us start our consideration of the commander's decision process by listing in Figure 41 (V2767) the factors a commander is taught to consider by the military colleges. Further let us recall the essential elements earlier found to apply to decisions by individual tank commanders. These were (1) a quantification of the terrain, (2) the construction of a mutually exclusive and exhaustive list of alternatives (the 8 squares plus the square occupied), and (3) a weighting system which described the relative desirability of these alternatives. We may expect the routine which effects a tactical decision for the company commander to follow this same pattern modified as may be required for the change in scale.

The first requirement is for a scheme to quantify the terrain. An examination of military documents discussing tactical doctrine shows quite clearly that the quantification must be in terms of irregularly shaped areas, approximately homogeneous with respect to some important terrain feature such as hill top, valley, forest, field, or village. Figure 42 (V2706e) indicates how the sample battlefield may be broken up into a small number of such areas. We may expect, therefore, that the second and third steps in the tactical decision process will involve a consideration of alternative positions and assault routes described in terms of the particular terrain feature areas they involve.

Now if we seek to compose a mutually exclusive and exhaustive list of the alternative assault routes and overwatching positions available to the company commander using all possible combinations of these tactical areas without restriction, then the number of such alternatives is surely astronomical. In other words there are uncounted billions of possible combinations of troops and routes implied by the number of tactical areas. We must, therefore, seek an approximation of the list of alternatives which is sufficient for our purposes and which represents fairly the number of alternatives actually considered by the company commander.

Tactical Decision

- Estimate of the Situation
  - Mission
  - Own Capabilities
  - Enemy Capabilities
  - Terrain
  - Select Decision
- Transmit Decision

Figure 41

Classical elements of the tactical decision process.

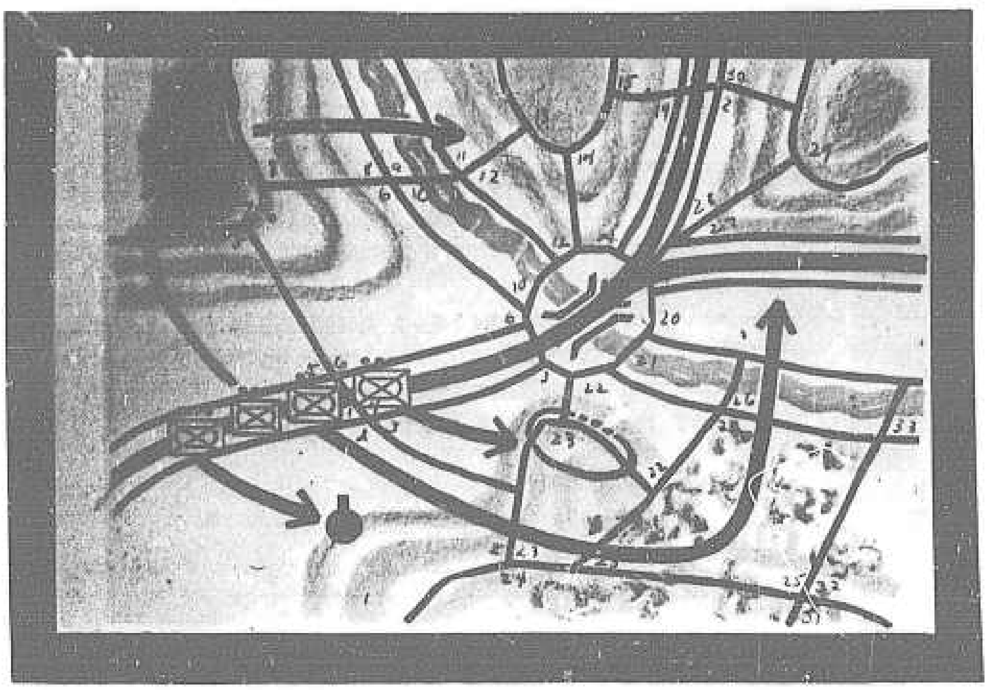


Figure 42

Identification of principal terrain features.

Alternative Assault Routes

Certain elementary constraints may be placed on the formation of assault routes to help to reduce their number. For example, the constraints applied may be (1) each assault route will start at the initial position of the unit and terminate at the terrain objective of the unit, (2) no particular assault route will pass through the same area twice, and (3) no particular assault route will pass other than directly between two adjacent areas. Figure 43 (V2706f) shows about 55 possible assault routes which meet the above requirements. Evidently additional restrictions must be applied to further reduce the number of alternatives.

It is desirable to avoid introducing sophisticated military judgments at this early stage in the TACTICS routine. We have not yet been able to formulate a single additional rule which is sufficient to further reduce the number of alternative assault routes to the order of ten without in the process discarding the (intuitively) sensible routes. However, it seems likely that by a judicious combination of the requirement "all routes must have no areas in common, except their end points" with certain simple geometrical considerations, the desired reduction may be acquired.

For example, Figure 44 (V2706g) shows 5 routes which remain when the above argument is applied to the 55 assault routes shown in Figure 43. Thus if one first selects that route which proceeds most directly from the present position to the terrain objective, and then determines the additional routes which are mutually exclusive in terms of the terrain areas they traverse, then only 3 assault routes remain. Figure 44 shows these 3 routes plus 2 additional routes which are distinct from the other 3 along most of their length.

Also identification of extremely impenetrable barriers or other undesirable terrain features will be used to reduce the number of assault routes quickly.

It is our contention that appropriate combinations of the above rules may always be formed which are sufficient to reduce systematically the number of competing assault routes to the order of ten. Clearly the application of rules of the above type may be effected by a digital computer.

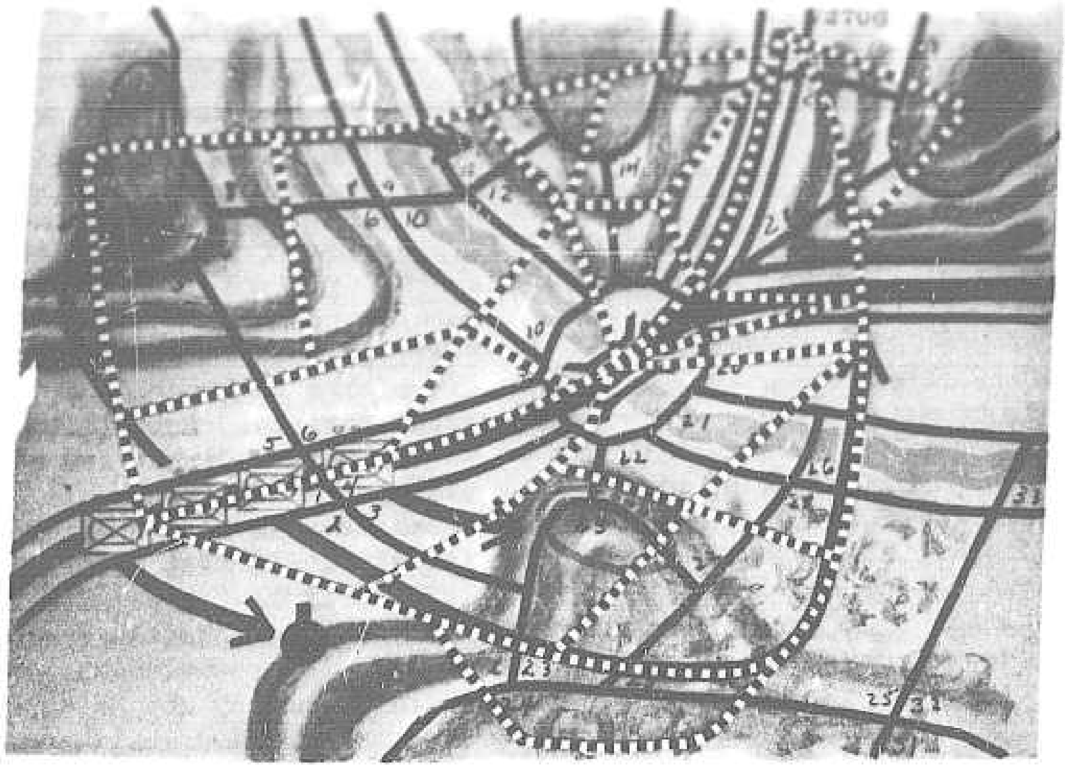


Figure 43
Dotted lines indicate location of all possible assault routes associated with given breakdown of terrain features

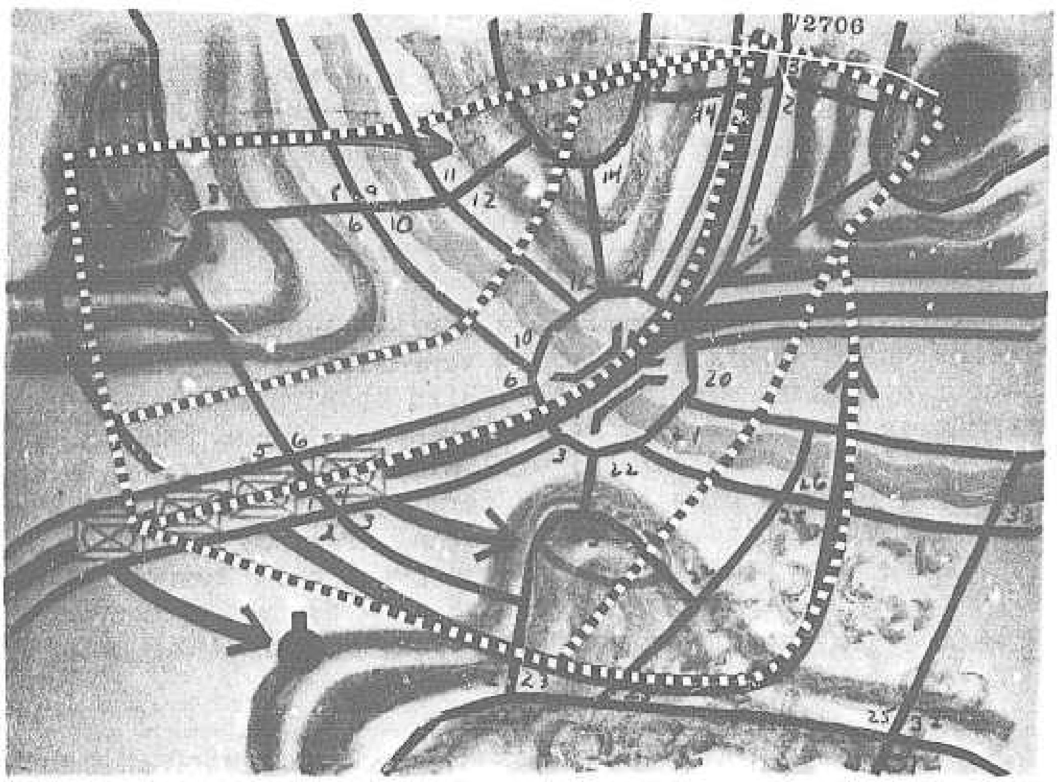


Figure 44
Dotted lines indicate principal assault routes

Alternative Task Force Organizations

The alternative attack plans considered by the company commander include not only various assault routes but also various combinations of troops to lead the assault while others stay behind and cover the assault with fire. Suppose, for example, that the company commander has 6 platoons under his command; 3 tank platoons, 2 infantry platoons, and 1 indirect fire or heavy weapons platoon. Various combinations of these platoons could be assigned the several missions. Again the number of possible permutations of these groups when combined with the order of 10 alternative assault routes gives rise to hundreds or thousands of alternatives — an unmanageable variety. But military tactical doctrines have much to say as to what are and what are not reasonable combinations of units. For example, a not improbable principle to be applied by the company commander is that tank units are not committed without accompanying infantry. If that doctrine is applied in the present case, Figure 45 (V3186) indicates permissable combinations. The first 4 combinations exhaust the possible 3 group task forces composed from the 6 platoons under the restriction that tank units are never assigned without infantry and may not be held in reserve. If the last rule is relaxed, 5 additional possibilities are obtained.

It should be clear that the application of doctrinal statements in the manner just described appears to be the fundamental justification for the existence of doctrine. In other words, the doctrines taught at military schools are very general and powerful rules based on much experience which the inexperienced can apply quickly to a problem so as to reduce it to manageable form. Therefore, the procedure just described is not proposed as an arbitrary or artificial one designed merely for matters of economy of computer time or to simplify our problem; rather we propose that this process faithfully simulates the general characteristics of the actual command decision process.

Weighting of Alternative Attack Plans

At this point we have composed a limited list of alternative battle plans which we will take to be approximately mutually exclusive and exhaustive. Therefore, only the third step remains — selection of one of these on the basis of a rating process. These ratings will be derived as follows. The computer will simulate the carrying out of each remaining assault plan in gross terms, the units being platoons instead of individual tanks; movement being from one terrain area to another terrain area instead of from one small grid square to another; casualties to be the expected casualties as a certainty instead of being determined by sampling from the population distribution. In this

POSSIBLE TASK ORGANIZATIONS

(T)	(I)	(S)
	3 GROUP TASK FORCES	
SUPPORT	OVERWATCH	ASSAULT
S	I	TTTI
S	TI	TTI
S	TTI	TI
S	TTTI	I
ST	I	TTI
ST	TI	TI
ST	TTI	I
STT	I	TI
STT	TI	I

Figure 45

way there will be determined for each attack plan the cost to Blue of achieving his objective in terms of equipment lost, casualties, and time consumed together with the corresponding cost to the enemy.

The procedure for doing this has been worked out in detail several years ago by Dr. W. E. Cushen3/ and is one of the two publications on which CARMONETTE is based.

"Value" of Battle Outcomes

Referring to Figure 46 (V2889) which lists a step by step structure of the command decision process carried out by the tactics routine we see we have reached step 4. But one important step remains. In step 5 we must combine the equipment and troop losses and time consumed into a single number which can then represent on a relative scale the "value" of that outcome. Clearly no detailed calculations are required, but a profound and difficult judgment is inescapable. We may not doubt that the company commander does indeed, by some obscure process, add dollars to time with lives at this stage in his deliberations. So must we. Without suggesting that there is available the comprehensive studies which will be required to effect such judgments, it is instructive to consider the initial orders our company commander may have received from his superior. He may have been told, "You must get to the top of that hill in two hours. Everything depends upon it." Or "Your objective is the top of the hill. But tomorrow we will be attacked by the enemy reserves. Therefore you should try, if at all possible, to keep your losses to 10 percent." Such statements unmistakably provide the basis on which our company commander will make this final "calculation." The general significance of such "value" concepts is discussed by N. Smith (ORO) in "A Calculus for Ethics: A Theory of the Structure of Value", Behavioral Science, Vol. I, No. 2 and 3, 1956.

The remaining two steps are now simple and straightforward. In step 6 one of the remaining alternatives is selected either because it has the highest "value" to Blue or (particularly in the case of the junior commanders) the selection is made by treating the ratings as probabilities.

In step 7 the necessary translation is made between the form in which the tactical decision calculations were carried out and the form required to implement the combat element calculations. Here, for example, intermediate terrain objectives are assigned which will cause subordinate units to move generally along the curved assault route selected. Here also values of the "a" coefficients and similar parameters are selected which will cause appropriate elements to remain in

Command Decision

1. **form** all combinations of routes - sub units
2. **discard** those in conflict with doctrine
3. **"simulate"** each remaining battle plan
4. **record** losses on both sides TIME · TROOPS · EQUIPMENT
5. **sum** "value" of losses
6. **select** course of action { high score / probability
7. **communicate** operations order

Figure 46

position and provide covering fire. Note that this requires that alternative sets of such values be previously stored in the computer so that one may be selected at this stage.

Initiation of Command Decision

The above procedure for effecting a command decision is sufficient to start the battle. It is necessary, however, to provide the criteria for initiating additional command decisions. Simple measures suggest themselves. For example, a company commander may be required to initiate a command decision calculation if (1) his own casualties reach some threshold value, or (2) if the assault unit fails to meet time deadlines, or (3) if units start running out of ammunition, or (4) if stated numbers of previously undetected enemy units enter the battle. Thus the tactics routine must have supplied to it continuously throughout the battle summary statistics concerning the course of the battle, limited of course by the effectiveness of the communications system. A complete tactical decision is then initiated only when one of these thresholds is passed.

It is estimated that the complete battle just described will take about 2 hours of calculations on the ERA 1103 computer and, in a slightly modified form, within the order of 10 minutes on the ERA 1103A computer. We may, therefore, expect to be able to play from some hundreds to the order of 10,000 battles. Efficient utilization of this capacity will require, of course, careful attention to the statistics of experimental sampling procedures which I have not discussed at all.

CARMONETTE vis-a-vis Field Experiments

It is obvious that the application of CARMONETTE requires the generation of an enormous quantity of input data. Further, the majority of the man-weapon performance data can only be accurately determined by costly field experiments which themselves are "reasonable" approximations of combat conditions. However, it would be an oversimplification to suggest, either, that a program of extensive field experiments is merely the servant of a series of tactical war games, or that nothing can be done with a tactical war game such as CARMONETTE without field experiments.

It is more meaningful to consider tactical war gaming and field experiments as equal and complimentary components of a rational program for the investigation of military problems. Each has the capability of increasing the productiveness of the other program. The tactical war game provides a theoretical structure which sheds light on what constitutes desirable and fruitful experimental programs. The results of field experiments will provide improved input data for the theoretical models and provide the basis on which the theoretical models may be tested for error and corrected. Neither comes first. Both must be developed simultaneously to their mutual advantage.

Interpretation of Battle Outcomes

The interpretation of the battle results which may be obtained is itself a problem as difficult as the construction and playing of the company sized games I have described. Essentially each series of games will produce a measure of the cost of the operation(s) under study in terms of equipment, troops, and time. Selection of preferred outcomes and therefore the identification of the preferred weapon systems poses the same question of "value" as was posed during the command decision calculations. This suggests two bases on which the results of a computer battle may be interpreted. (1) The battle is considered to be typical of a long series of battles. In this case the question is merely one of bearable levels of attrition. (2) The battle may be a critical step in the implementation of some higher level and very important war plan. In this case the significance of the results is not fairly measured by the losses suffered during the battle but only by the contribution of the battle outcome to the success of the higher level war plans. In fact, we may expect that our primary concern will be battles of the latter type since the weapon systems under study will include radical doctrines and hardware with potentially drastic influences at every level. If this is the case, then the interpretation of the results of company sized war games will require the analysis of battalion sized war games. The interpretation of the battalion sized war games will require interpretation in terms of their influence on still higher level war games. We have, therefore, a requirement for tactical war games at all levels.

A Hierarchy of War Games

Figure 47 (V3185) extends this notion to its inevitable conclusion. The problems leading to military operations at every level all involve the same degree of complications as impelled us to apply CARMONETTE to the company sized war game. We must therefore attempt to construct a hierarchy of games, each taking as input the results of analysis of a series of lower level games in combination with the other factors to which we alluded in Figure 1.

We propose that a description of CARMONETTE as treating of a company sized action is largely but a matter of interpretation. Thus, if we choose to interpret the individual combat elements not as tanks and infantry squads but instead as platoons of tanks and platoons of infantry, with the grid squares as being 300 yards on the side, then a CARMONETTE battle may encompass a battalion. Ultimately we may have sufficient data to permit interpretation of the individual combat elements in CARMONETTE as divisions with each grid square 10 to 20 miles on a side. At this point, CARMONETTE might permit analysis of complete tactical operations within a theater.

It is in this more general sense that the logical structure of CARMONETTE is offered as a tool for the analysis of the effectiveness of new weapon systems in their operational context — a tactical war-gaming system applicable to all tactical levels.

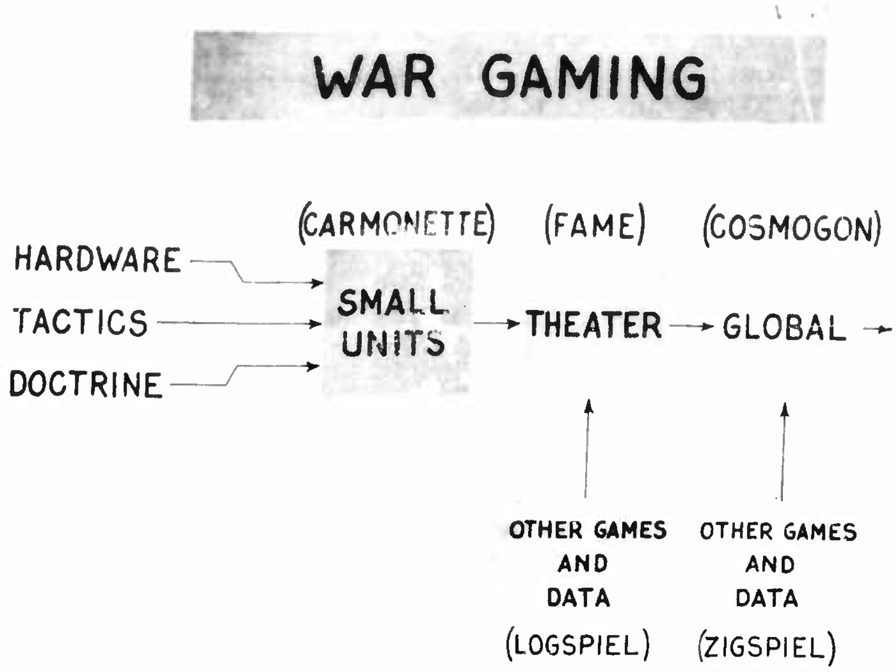

WAR GAMING
(CARMONETTE)
(FAME)
(COSMOGON)
HARDWARE
TACTICS
DOCTRINE
SMALL UNITS
THEATER
GLOBAL
OTHER GAMES AND DATA
(LOGSPIEL)
OTHER GAMES AND DATA
(ZIGSPIEL)

Fig. 47

Training

Although ORO is not directly responsible for the study of training procedures, it is easily seen that the CARMONETTE system of war gaming can be applied to complement a training program which incorporates war gaming (or command post exercises) as a means of instruction or testing. In such an application the computer calculations would serve two purposes:

1. Relieve the students of the necessity to maintain an elaborate bookkeeping system;

2. Provide a vastly increased realism in the treatment of the operation of subordinate units not otherwise played during the exercise.

Any of a number of commercially available large scale digital computers can be programmed to simulate battle based on the concepts described above. However, mechanical or electrical additions to the basic computing equipment would be desirable to improve the speed and convenience with which the control group and student players may communicate with the computer. Existing input-output equipment can be adapted for this purpose. Of special interest is a "television-like" projection system[4] to which the computer is directly connected and which projects the minute-to-minute status and position of all subordinate units as the battle proceeds. The Red, Blue and Control staffs can each, separately, be in communication with the machine, subject to the proper intelligence limitations. The operators could then interupt the machine calculations at any time to inject new orders or otherwise alter the course of the battle calculations in accordance with the purposes of the program of instruction.

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